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TO THE MEMBERS OF THE SECTION ON OPHTHALMOLOGY
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All the completed papers for the program of the Section on Ophthalmology of the American Medical Association, New York City Session, 1917, will be found herein. Provision has been made for notes on the margins of the pages and on the blank page following each paper.

Following the plan in force during the last few years, the papers will not be read before the Section, but each author will be allowed not to exceed ten minutes in which to summarize the points in his paper and to introduce discussion. The member appointed to open the discussion of any paper will be allowed not to exceed ten minutes and subsequent speakers five minutes. Any one who has written out his discussion is urged to hand it to the stenographer promptly. (It should, of course, be remembered that written discussions must not exceed the limits of length imposed by the time allowed to each discusser; that is, about 1,000 words for those who open discussions, and about 500 words for those who follow. Discussers will naturally prefer to see themselves that their discussions conform to these requirements, rather than run the risk of having their remarks condensed by other hands.)

Attention is called to the desire on the part of the officers of the Section to have an exhibition of pathologic specimens, photographs, charts and printed histories of rare and interesting cases. Members are also invited to exhibit new instruments and appliances which may be of interest to the members of the Section. Those desiring to contribute to this feature are requested to correspond with the Secretary of the Section.

George S. Derby, Secretary.

William Zentmayer, Chairman.

THE BOUND TRANSACTIONS

All of the papers found within, together with the formal discussion of these papers at the New York City Session, will be printed and bound in cloth, thus constituting the Transactions of the Section on Ophthalmology of the American Medical Association for 1917. Members of the Section and others may obtain these bound Transactions at $1 a volume by sending subscriptions to the American Medical Association, 535 North Dearborn Street, Chicago, on or before July 10, 1917. After the volume is published the price will be $1.50.

George S. Derby, Secretary.

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Since only enough books are printed to supply the demand some physicians who have not attended the Association sessions, or who have neglected to send in their subscriptions before the books were published, have been disappointed in not being able to secure the Transactions desired.

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CHIEF FUNCTION OF THE OBLIQUE MUSCLES OF THE EYE

SOME OBSERVATIONS WHICH SEEM TO LEND SUPPORT TO A LONG DISCARDED THEORY *

SAMUEL THEOBALD, M.D.

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BALTIMORE

In endeavoring to find an answer to the question what is the chief function of the oblique muscles of the eye, it is important that we should take into account the fact that these muscles are not peculiar to man, but that, on the contrary, they are found almost without exception, in all vertebrates — the only exception being the myxinoids or lampreys. This fact, which shows that they were evolved many thousands of years before even the anthropoids made their appearance, seems to indicate that they have a much more important function to serve than that which is commonly attributed to them in man — that their chief office is to counteract the faulty action of the superior and inferior rectus muscles, owing to the fact that the direction of the pull of these muscles does not correspond with the sagittal axis of the eyeball. Surely these conditions do not exist generally in vertebrates, and, therefore, could have had no bearing on the evolution of the oblique muscles.

In the early part of the last century, the commonly accepted view, which, according to Prof. Joseph Pancoast, dates back to the time of Boerhaave, was that the oblique muscles were the antagonists of the recti and, especially, that they prevented the latter, when acting, from retracting the eyeball into the orbit. This view, however, was not without its opponent, and the

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first instance I have found of its rejection occurs in an article by Green,[1] in which the author says:

> To the favorite doctrine of most anatomical writers, we cannot subscribe, viz., that the obliqui are the *antagonists* of the recti. This error is based on another, viz., that there is a *necessity* for antagonism. i. e., that the recti *retract* the ball from its ordinary position in the socket.

It is to be regretted that, at least in the published abstract of his paper, the writer adduces no facts or observations to sustain these very positive assertions.

Coming down, now, to a more recent time, we find that so careful an observer as Fuchs held that some provision *is* necessary to prevent the eyeball, when performing its movements, from leaving its place in the orbit, and, according to his view, it is the bulbo-orbital fascia which provides against this misadventure.[2] He says:

> By means of this system of fascia pervading the orbit, the contents of the latter are fixed in place. It is owing to them that the eye does not leave its place when performing its movements, but turns about a fixed center.[3]

This view of the action of the bulbo-orbital fascia, I may add, is held, also, by Duane,[4] another high authority on the ocular muscles and movements, who recently said:

> The position of the eye in the orbit seems to me to be governed mainly by the fascial bands (including the cheek ligaments) that connect the eye and the muscles with the orbital walls.

It requires no little temerity on my part to call in question the competence of the bulbo-orbital fascia to do what these authorities agree in holding it does do — to prevent the eye from leaving its place in the orbit, when the rectus muscles contract, and to cause it to turn about a fixed point.

---

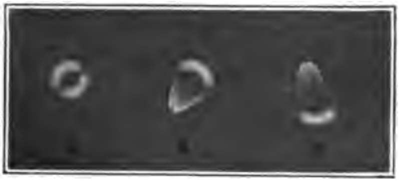
1. Green, C.: On the Functions of the Oblique Muscles of the Eye, abstr., Boston Med. and Surg. Jour., 1845, **32**, 191.
2. Motais, discussing the fixity of the eyeball in the orbit, in his treatise on the "Anatomie de l'appareil moteur de l'œil de l'homme et des vertébrés" (1887, pp. 123-124), answers the question: How can an organ with such yielding walls, immersed in a soft mass, and subject to such rapid movements, maintain a fixed position, by saying that it is due to the combined action of several anatomic elements, which he mentions in this order: the antagonism of the rectus and oblique muscles, the bulbo-orbital fascia, with its ligamentous wings, and the cushion of adipose tissue which occupies the deeper portion of the orbit.
3. Fuchs: Text-Book of Ophthalmology, fourth American edition, p. 689.
4. Personal communication to the author.

To effect this end, it would seem there must be tense, inelastic bands of fascia connecting the sclera or Tenon's capsule with points on the orbital walls anterior to their attachments to the eyeball. That these bands must be, as I have described them, *tense* and *inelastic,* appears obvious; otherwise, having no power of contraction, they could not effectually oppose the very real backward pull of the several rectus muscles.

Do such fascial bands exist? And, if they did, would they not, acting as check ligaments, necessarily interfere with the movements of the eye?

These questions, it seems to me, admit of but one answer: No such bands do exist, and, if they did, the rotational movements of the eyeball would certainly be seriously curtailed.

Accepting the view of Fuchs, which I understand that Duane endorses, that *some* provision is necessary to prevent the eye being pulled back into the orbit by contraction of the rectus muscles, and thus enabled to rotate about a fixed point, it would appear that we must fall back on the discarded theory of the supporting or antagonistic action of the oblique muscles for a solution of the problem.



Subjective light sensations seen in left half of visual field by right eye: *a,* produced by lateral rotation of the eye; *b,* by downward rotation; *c,* by upward rotation. The upper light sensation, in each instance, is caused by contraction of the inferior oblique, and the lower by contraction of the superior oblique.

If this view is correct, it would seem to follow that the oblique muscles must take part in all movements of the eye.

Observations which I have recently made of certain subjective light sensations, manifestly caused by contraction of these muscles, appear to show that such, indeed, is the case, with the possible exception of the conjoint action of the interni in effecting convergence. On awakening in the early morning, while the room is still dark, I have observed, projected somewhat into the upper visual field of each eye and in juxtaposition, always one above the other, two subjective light sensations, one decidedly sharper than the other, on rotating the eyes widely in any direction. On converging the eyes strongly, which I found not so easy to do in the dark, I have thought I obtained similar light sensations, but they were less well defined and more evanescent than those produced by rotating the eyes vertically or laterally.

When the eyes are turned upward, in which movement the inferior oblique should act more energetically than the superior, the brighter and better defined light sensation, as we should expect, is, as shown in the illustration above, the less defined one, produced by the feebler action of the superior oblique, below. When the eyes are turned downward, the superior oblique being then called into more energetic action, the brighter sensation is below, the feebler one above. When the eyes are rotated laterally, the upper and lower light sensations do not differ appreciably in intensity or in form, indicating, it would seem, that in these movements the obliques act with approximately equal energy; and the same is true of those which, I believe, I observed on converging the eyes. The phosphenes seen in the left half of the visual field are, of course, projected from the right eye, and vice versa.

I may add that the light sensations described rapidly decline in brilliance, and, with the exception of those caused by rotating the eyes upward, are best observed with the lids closed, and, further, that repeated attempts to produce them, by energetically rotating the eyes, presently gives rise to an ill-defined aching sensation, most noticeable, perhaps, in the region of the trochlea of the superior oblique.

If further observation should show that these subjective sensations do not occur in convergence of the eyes for a near point, a possible explanation might be that in regarding near objects a certain amount of displacement of the eyes backward and inward, in addition to their inward rotation, may not be harmful, may, indeed, even be helpful, so that conjoint action on the part of the obliques under such circumstances would not be called for.

As to the competence of the oblique muscles to counteract the backward pull of the recti, and to maintain the eyeball in its proper position in the orbit, it would seem that they are fully equal to the task. With their fixed attachments close to the orbital border — that of the inferior oblique actually and that of the superior oblique potentially, because of its trochea — and passing from these points to grasp the eyeball near its posterior pole, one from above, the other from below, and, moreover, unlike the bulbo-orbital fascia, having the power to contract, so as to oppose with exactness the backward pull of the recti, the oblique muscles appear to be entirely capable of causing the eye to rotate, with precision, about a fixed center, a provision so essential to accurate vision, and, especially, to perfect binocular vision.

If it be objected that to do this the direction of the pull of these muscles would have to be straight forward, it may be pointed out that the pull of the recti, especially the superior and inferior recti, is not straight backward, and that the direction in which the energy of the obliques is exerted seems really to be that best adapted to accomplish the end in view.

That the oblique muscles serve other important ends, especially in preventing the superior and inferior recti from tilting the vertical axis of the eye, and in assisting those muscles to rotate the eyeball upward and downward, is, of course, not to be denied; but that their *chief* function is that which I have set forth seems, to me, at least, to admit of but little doubt.

Cathedral and Howard Streets.

MEMORANDA

BINOCULAR SINGLE VISION

LEAVING OUT THE CONSIDERATION OF THE COLOR PERCEPTION AND THE PROBLEMS OF STRABISMUS *

E. E. BLAAUW, M.D.

BUFFALO

When I take the liberty of asking your interest for a few moments for a subject on which every one of us has pondered some time in his life, I do it because the subject has not been approached in these meetings since 1903, when Dr. N. M. Black spoke about the development of the fusion center in the treatment of strabismus. I have found only three papers since that date in the American ophthalmologic literature, one in 1903 by Dr. E. R. Lewis, and two during 1916 by Drs. A. Brav and G. A. Shepard. Looking over the American textbooks of ophthalmology since that date, I find that the theoretical treatment of the subject is not without some points about which we may talk for a moment, and that the examination for binocular single vision (B. S. V.) in its highest development, namely, the perception of depth, is hardly touched on . The result is that this examination is seldom done, although the perception of depth is of the highest value and can be expressed in terms as accurate as the visual acuity, if we can come to a general undestanding. It is high time that more stress should be laid on this function of the binocular organ.

To substantiate what I have said about the textbooks, I may be pardoned if I briefly communicate what I have found:

Fox[1] says:

> Perfect binocular vision, or the blending of two images into one, occurs only when the two images fall on correspond-

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[1] Fox, L. Webster: A Practical Treatise on Ophthalmology, 1910, p. 678.

ing points of the two retinae. These points are as follows. . . . Any disturbance of the harmonious action of the ocular muscles causes the images to be formed on noncorresponding points, and binocular vision is destroyed. This also occurs occasionally after cataract extraction due to malposition of the pupil. Diplopia does not always occur, because the image formed in the nonfixing eye is blurred by the dioptric system, and its perception is retarded by being thrown upon a portion of the retina less sensitive than the fovea centralis. Usually, however, by careful testing diplopia can be demonstrated in imperfect muscle balance.

Ball[2] says:

> Binocular vision means the union in one single impression of images received simultaneously on both retinae. . . . Two chief theories have been proposed for the solution of the problem: (1) the theory of identical points, and (2) the theory of projection. The latter theory assumes that the retino-cerebral apparatus, by a process of mental projection of the images into space, has the power of appreciating the shape and size of an image, as well as the direction of the rays of light, which form it. While the limits of this treatise will not permit an extended discussion of the subject of binocular single vision, it will be necessary to consider the first theory more extensively.
>
> The theory of identical points assumes a correspondence of each point of one retina to a similarly situated point on the retina of the other eye. When the visual axes are directed toward a far distant object, the visual axes then being parallel (Fox states, p. 678: "The position of rest of the ocular muscles is probably divergence of the visual axes about 8 to 10 degrees from parallelism"), a correspondence actually exists; but when the visual axes converge, the points do not converge. Furthermore, a part of each retina has no corresponding points in the other. This is due to the fact that the actual center of the retina is not at the fovea centralis, but lies nearer the nasal side. So long as the images of a point are within the horopteric circle they fall on corresponding parts of the retina. Images of a point outside this circle do not fall on corresponding points.
>
> [Then the description of the horopter of Johannes Mueller follows. He continues:]
>
> Since the doctrine of identical points is true for only some visual acts, an attempt must be made to explain binocular single vision without the horopter. Such objects as are situated outside the horopter are seen double, but it is possible to obtain only a single cerebral impression of them. Thus the expert ophthalmologist keeps both eyes open while examining the fundus. The image seen by one eye in this

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[2] Ball, James Moores: Modern Ophthalmology, 1913, p. 75.

case is ignored. Under some circumstances a new mental picture of two combined dissimilar retinal impressions is made. Thus, ideas of solidity and depth are obtained in binocular vision by the mental combination of dissimilar retinal impressions, as in using the stereoscope. . . . One reason why nonidentical points yield good vision is that vision becomes less distinct as we pass from the center of the retina, and the observer learns to neglect the blurred peripheric images, while giving attention to those formed on the fovea.

Stereoscopic Vision: This is another name for binocular vision, or the sense of depth. The law of identical points was supposed to be absolute up to the time that Wheatstone constructed his stereoscope. This shows that the perception of depth is caused by a slight nonidentity of the two retinal images. An object appears to us to be solid, when each eye views it from a different point, as in normal vision.

G. E. deSchweinitz[3] (1910, p, 674) says:

If the associated movements of the eyes were not thus regulated by equal impulses from the coordinating center single vision would not be possible, because the image of any object would not fall upon corresponding points of the two retinas. . . . If, for any reason, the movements of the eyes become disarranged so that the images do not fall upon corresponding or identical areas, the images become double. . . . [Page 50:] The images are projected in different positions, when they are not formed on identical points of the two retinas. [Page 718:] It is often difficult to ascertain whether true binocular vision exists . . . and successful bar reading, usually quoted as a sufficient test, is, according to Priestley Smith, not without its fallacies. The author tests as follows: . . . if he can see all three at once and in a line he is *probably* using both eyes, . . . if with each eye alone he sees two, but with both eyes three, the proof is *fairly* positive. [Italics mine.]

Weeks[4] says:

This condition in which both eyes are accurately directed at the object at which one of the two is looking is called binocular fixation, i. e., binocular fixation means that both eyes are straight.

Corresponding Points: Binocular single vision: . . . The act of thus compounding two retinal impressions so that but one mental concept is formed out of them is called fusion. . . . And any image which forms its retinal images on the corresponding points in the two eyes will always appear single (law of binocular single vision).

---

[3] DeSchweinitz, G. E.: Diseases of the Eye, ed. 6, 1910.

[4] Weeks, J. E.: A Treatise of Diseases of the Eye, 1910, p. 709.

The usual schematic picture representation is then given, when the author continues:

> While C. will appear double, because its images are formed on noncorresponding points.
>
> Diplopia: The converse of this proposition is also true; that is, any object whose retinal images are not formed on corresponding points in the two eyes appear double.
>
> When the two eyes are both fixing the same object that object and a large number of outlying objects, too, will appear single, because their respective images fall on corresponding points. All other objects, however, will appear double, and this will be particularly the case with objects either nearer or more remote than the object looked at. This physiologic diplopia is regarded as one of the most important of the factors enabling us to appreciate depth and relief (stereoscopic vision). We are not, however, usually aware that these outlying objects are really double, so that, in general, when we use binocular vision everything is apparently single to us.
>
> Exceptions to Law of Diplopia: It must be noted that while binocular fixation is regularly associated with binocular single vision and absence of binocular fixation with diplopia, this association does not hold for all cases. A man may fix an object with both eyes, and yet see it with but one (uniocular vision) . . . or, because, as often happens in a cured squint, the image formed by that eye is mentally suppressed. In this case, then, there is binocular fixation, but not binocular single vision.
>
> Anomalous Diplopia: In other rather rare cases there may be binocular single vision, but not binocular fixation.

Under the test of binocular vision on page 732 is described:

> 2. Maddox rod. In case he has binocular vision pat. will see both the streak and the flame. If he has also binocular single vision the streak and the flame will be superimposed.

—as if binocular single vision cannot be present, when the streak does not go through the light!

In the "American Encyclopedia of Ophthalmology" the subject of binocular single vision on page 970 is identical with the one referred to above by J. M. Ball. It is followed by the "ingenious illustration of the single character of binocular vision by Savage, in his 'Ophthalmic Myology,'" which to me appears nothing else than a mere obscure description of the correspondence of the two retinas. Just as his isogonal circle (p. 2253) is simply another name for horopter. My objection chiefly is to the following sentence: "In obedience to the law of projection the one eye sees the line located in space as the other eye sees it; that is definitely related to the median plane of the head, and there is but one object." . . .

Then comes another paragraph, page 973: "Binocular vision. This is the faculty of using both eyes so that they see together without doplopia," which is followed with a discussion about binocular single vision; and — to show the kind of work — a reprint is given from Hill[5] from the "System of Diseases of the Eye," which appeared in the nineteenth century: "In man stereoscopic vision reaches a high state of development, although, owing to the prominence of the bridge of the nose, it probably does not take such complete possession of the retina as it does in the monkey"! Where in the world have ever experiments on monkeys' sense of depth been performed?

Gibbons[6] says:

> Each eye projecting its image in a different direction in space causes the two eyes to see a single object as two. There is binocular diplopia, or ***double binocular vision.*** [Italics mine.]

In the two volumes, about 900 pages devoted to the muscles of the eye, Dr. Lucien Howe devotes two thirds of one page to this most fundamental point of the highest practical interest (p. 133).

> Suppression of diplopia is physiological: When both eyes are fixed upon an object in front, evidently all other objects lying in that plane—or indeed anywhere else except in the circle of the horopter—are focused on parts of the retina in the two eyes which do not correspond with each other. This of course produces double vision, and if we were accustomed to take cognizance of all these double images the result would be confusing in the extreme. That is easily seen by pressing upon one eye in any direction, so as to produce diplopia. The fact is, therefore, that the normal eye is accustomed to suppress those images which do not fall on the fovea, and to such an extent that we are practically unconscious of it. This is accounted for in various ways, and perhaps no better explanation has been given than what Javal calls "the antagonism of the visual fields." Or, as Tscherning says: "It is sometimes the images of one eye that prodominate, sometimes those of the other, and as long as we see in a part of the visual field images with one eye, those of the other eye

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[5] Hill: System of Diseases of the Eye, 1, 390.

[6] Gibbons, Edward E.: The Eye, Its Refraction and Diseases, 1904, p. 140.

are completely suppressed." Javal considers that this has an important bearing on some forms of deviation with which we will have to deal later.

The author is not very much at ease with the working of the usual stereoscope, as is shown on page 306, Volume I:

> Most of the refracting stereoscopes are made so that the object is viewed only with *considerable convergence.* [On page 86, Volume II:] In the latter [the stereoscope] the convergence is *increased* while the accommodation is diminished, and moreover, with the latter there is a fusion of two different images. [Italics mine.]

The same misunderstanding of this instrument is expressed by the writer of the Hogg's test for simulated blindness:[7]

> A person who has normal vision in the two eyes and who looks through the prisms of a stereoscope fuses and involuntarily superimposes the two *lateral* images in a single combined image. [Italics mine.]

To show that outside the United States also no consensus of opinion has been reached, I will quote from the American translation of Roemer's book:[8]

> Certainly when two corresponding places on the retinae are stimulated by one and the same object, a single sensation is always produced. When two corresponding places are stimulated dissimilarly the different sensations appear in one and the same line of vision, and all objects that delineate themselves on corresponding places in the retina appear to be at the same distance as the fixation point. On the other hand, stimulations of not corresponding, or disparate, places on the two retinae produce double images of the object in question. This is shown from an old experiment. . . . We learn from this experiment that all points nearer the retina than the point of fixation create retinal images with crossed diplopia. . . . This is because most objects are delineated on disparate places on the retina during vision with converging visual lines. There are several causes why we do not notice these double images ordinarily when looking at near objects, under normal conditions: 1. The images of objects produced on the periphery of the retina are much more indistinct than those of the central portion. These images do not make as strong an impression on our consciousness as those on the fovea. We do not notice the things pictured on disparate places of the retinae because our attention is directed wholly

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[7] American Encyclopedia of Ophthalmology, p. 1181.

[8] Roemer, Paul: Text-Book of Ophthalmology, trans. by M. L. Foster, New York.

to the fixation point. In addition to this, even images which lie on corresponding places in the retinae by no means always appear simultaneously in the proper line of direction. The images conflict with each other, so that we have what is known as the antagonism of the visual fields. One or the other image may appear alternately in the line of direction appertaining to the identical points. Finally, it has been proved that, within certain limits, objects may be seen with binocular single vision that lie on disparate places in the retinae, but such objects appear to be nearer, or farther away than the point of fixation. A physiological phenomenon, however, claims our chief interest at this time. We do not notice the double images because at the instant when our attention is directed to a disparately delineated object our eyes immediately and quite automatically execute such a movement as will bring the image upon the center of the retina. . . . The movements of the eyes that displace the retinal images from disparate to corresponding places are called fusion movements.

It is as true now as in the days of Joseph Le Conte that a "discussion of binocular (single) vision is by far the most fascinating portion of the whole subject of vision."

Following the development along historical lines, it must be acknowledged that the mathematical treatment as well as the psychologic interpretation has done more harm than good. The mathematical treatment has made its understanding needlessly complicated, while the psychologic explanations were mostly nothing else than disguised metaphysics — or "the filling of the belly with east wind" (Book of Job).

The times are ripe to treat the subject of binocular single vision according to the rules of the science to which the subject belongs. It is essentially a physiologic process, which must be interpreted from the evolutionist standpoint.

We find in the lower vertebrates the two eyes on the sides of the head; this position changes to a more forward one with an ever enlarging common field of vision until in the Primates we see the highest development. Every animal which has two eyes has binocular vision, as this term means only "vision with two eyes." We should therefore not use this term indiscriminately for binocular single vision. We cannot know how these animals see, just as we do not know whether or not those animals which have their eyes in the front part of their head can appreciate depth and solidity, as we do. A part of this lower form of vision, from the human side, or rather fundamental form of vision, is still found in man, namely, we have a simultaneous impression in the temporal parts of both fields independent from each other. In man we find a common field of vision, a part of which possesses a new faculty, which is absent in the single eye — anyhow to the perfection as it exists in both — namely, of appreciating depth and solidity, sometimes called "stereoscopic vision." It will therefore not be strange to find different degress of vision, from simultaneous vision with alternating macular perception and slight or no appreciation of depth to the highest acuteness of the appreciation of the distance of two points, a quarter of a minute being the size of the angle under which the two eyes can separate the position of two points, under favorable conditions. The great superiority of man over the lower animals is the potential faculty of a continuous development during his individual life. His newly acquired faculties are the least stable, are more apt to develop under individual effort, are more vulnerable in the upgoing line as well as in the downgoing one, with other words, a small obstacle may prevent the full development, as well as the fully developed acquisition can be more easily damaged. From this it results that the apparatus for binocular single vision can be perfected through exercise, and also that it can more easily change independently of the apparatus of simultaneous vision, which is the older and the more stable through heredity.

When we see, we react to a stimulus of the outside world. Electromagnetic vibrations, which go out from some outside object, stimulate the retina, which stimulation is propagated to the brain. Here a double process occurs, a sensory and a neuromotor. The sensory process travels through cerebral paths, reaching the stimulated part of the retina, and then projects into the outside world its image, which under normal circumstances covers the object with mathematical precision. The neuromotor part directs the position of the visual lines. We know not the external world as it is, we see because we have eyes. "The eye creates the light." This does not mean that no objective world exists; it means that our appreciation of the world is entirely subjective. This conception presupposes that the line of impression (the line from the luminous object toward the corresponding point in the retina) is not the same as the line of projection (the line from the retinal point toward the corresponding point of the image). This difference becomes clear for the condition, when for instance, the eye is displacd by mechanical means, or when one looks through a prism: we see then the image where nothing exists and where the object is we see nothing. We should not speak of a prism which "deflects the rays of light toward its base," but a prism which moves the image in the direction of its apex. The difference of the line of impression and the line of projection becomes especially valuable for the understanding of what happens, when we see stereoscopically. The projection of the visual image is not an "act of judgment," but the product of a sensory reaction and the result of an organic property of the nervous elements. The projection is inherent to the function of the visual apparatus; it follows with every luminous stimulation or mechanical excitation of the retina; it follows by necessity, automatically.

Wheatstone gave all the essential facts of the stereoscopic process when in 1838 he published in the *Philosophical Transactions* his "Contributions to the Physiology of Vision."

Euclid, more than 2,000 years ago, knew that the two eyes see two dissimilar pictures or portions of bodies. Galen has described with great minuteness in his work, "De Usu partium corporis humani," the various phenomena which are seen when we look at bodies with both eyes, and alternately with the right and left. We also find this dissimilarity mentioned by Leonardo da Vinci (after Brewster).

On account of its importance I will quote now Wheatstone (his entire essay should be reprinted as a classic):

> If the optic axes of both eyes are parallel, the perspective projections of it, seen by each eye separately, are similar, and the appearance to the two eyes is precisely the same as when the object is seen by one eye only. There is, in such case, no difference between the visual appearance of an object in relief and its perspective projection on a plane surface. But this similarity no longer exists, when the object is placed so near the eyes that to view it the optic axes must converge; under these conditions a different perspective projection of it is

seen by each eye, and these perspectives are more dissimilar as the convergence of the optic axes becomes greater. It being thus established, that the mind perceives an object of three dimensions by means of two dissimilar pictures projected by it on the two retinae.

I have given ample proof that objects whose pictures do not fall on corresponding points of the two retinae may still appear single (Fig. 1 *A*). Similar pictures falling on corresponding points of the two retinae may appear double and in different places (Fig. 1 *B*). The two strong lines, each seen by a different eye, will coincide, and the resultant perspective line will appear to occupy the same place as before; but the faint line which now falls on a line of the left retina, which corresponds with one of the coinciding strong lines, viz., the vertical one appears in a different place. . . . This experiment affords another proof that there is no necessary physiological connection between the corresponding points of the two retinae—a doctrine which has been maintained by so many authors. . . . Many of the supporters of the theory of corresponding points have thought, or rather have admitted, *without thinking,* that it was not inconsistent with the law of Aquilonius. . . . The same reasons, founded on the experiments in this memoir, which disprove the theory of Aquilonius, induce me to reject the law of corresponding points as an accurate expression of the phenomena of single vision. According to the former, objects can appear single only in the plane of the horopter: according to the latter, only when they are in the circle of single vision, both positions are inconsistent with the binocular vision of objects in relief, the points of which they consist appearing single though they are at different distances before the eyes. I have already proved that the assumption made by all the maintainers of the theory of corresponding points, namely, that the two pictures projected by any object in the retinae are exactly similar, is quite contrary to fact in every case, except that in which the optic axes are parallel.

It now remains to examine *why* two dissimilar pictures on the two retinae give rise to the perception of an object in relief. . . . The complete solution is far from being so easy as at a first glance it may appear to be, and is indeed one of great complexity. I shall merely show the most obvious explanations which might be offered, and show their insufficiency to explain the whole of the phenomena.

It may be supposed that we see but one point of a field of view distinctly at the same instant, the one, namely, to which the optic axes are directed, while all other points are seen indistinctly, that the mind does not recognize them to be either single or double, and that the figure is appreciated by successively directing the point of convergence of the optic axes successively to a sufficient number of its points to enable us to judge accurately of its form. . . . Were it entirely so, no appearance of relief should present itself when the eyes remain intently fixed on one point of a binocular image in the stereoscope ("the instrument which has the property of representing solid figures"). . . . Were the theory of corresponding points true, the appearance should be that of superposition of the two drawings, to which, however, it has not the slightest similitude.

Another and a beautiful proof that the appearance of relief in binocular vision is an effect independent of the motions of the eye, may be obtained by impressing on the retinae ocular spectra of the component figures. The drawings should be made of broad colored lines on a ground of the complementary color, for instance, red lines on a green ground, viewed with the eyes fixed only to a single point of the compound figure; the drawings strongly illuminated and after a sufficient time the eyes must be carefully covered to exclude all external light. A spectrum in relief will then appear before the closed eyes: sometimes the right eye spectrum will be seen alone, sometimes that of the left eye, and at those moments when the two appear together, the binocular spectrum will present itself in bold relief. As in this case the pictures cannot shift their places on the retinae in whatever manner the eyes

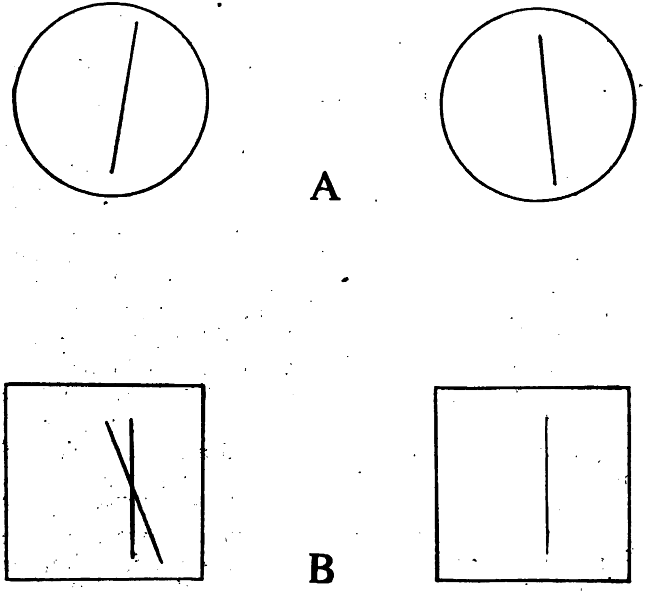

Fig. 1.

be moved about, the optic axes can during the experiment only correspond with a single point of each. When an object, or a part of it, thus appears in relief while the optic axes are directed to a single binocular point, it is easy to see that each point of the figure that appears single is seen at the intersection of the two lines of visible direction in which it is seen by each eye separately, whether these lines of visible direction terminate at corresponding points of the two retinae or not. But if we were to infer the converse of this, viz., that every point of an object in relief is seen by a single glance at the intersection of the lines of visible direction in which it is seen by each eye singly, we should be in error. On this supposition, objects before or beyond the intersection of the optic axes should never appear double, and we have abundant evidence that they do.

Wheatstone showed, therefore, that corresponding points, which are points lying on the horopter of Johannes Mueller, are seen singly, but also points within or without are seen singly, only they are appreciated at a different place in space. He even puts down the law of intersection of the secondary axes, elaborated later by Giraud-Teulon and Parinaud. For better understanding we need consider what happens when we see stereoscopically. This should be done without an instrument. However, the instrument as such does not produce the phenomenon; it only enlightens the procedure. We need a reproduction of an object as seen with the right eye and as seen with the left one; these pictures are slightly different. If we now relax our convergence so that we see with as much as possible parallel visual axes, four images will appear in crossed double images; those of the left eye are projected to the right, those of the right eye to the left. When the two middle images come together (fuse), we receive the sensation of depth quite involuntarily, automatically, independent from any muscular action, what Dove (1841) demonstrated by using the electric spark. The two lateral images play no part in the process, and they are the ones which are shut out by the partition of the stereoscope, which also by its prisms with the apexes inward facilitate the parallelism of the visual axes and through their positive lenses enlarge the impressions.

There is a reality in the unreality of these pictures. They are virtual images in the sense that they do not respond to an objective reality; they can be compared with refractive or reflected images; they can be measured experimentally and the conditions calculated which vary their localization in space, their size and their depth. If, for instance, we take the two pictures of a fulcrum, the distance at which the smaller circle is seen from the base depends entirely on the degree of excentricity (stereoscopic parallax), their distance from each other. We need only to accept the fact, to which we have agreed regarding the chief axes of projection, that we see the object in space where they intersect, that this also exists for all secondary axes of projection (law of Giraud-Teulon and Parinaud). The production of the stereoscopic relief follows from this law. If the larger circles fall on corresponding points, the smaller will before fusion form homonymous or heteronymous images and after fusion be projected behind or before the large circle. The position in space is determined by the intersection of the principal axes.

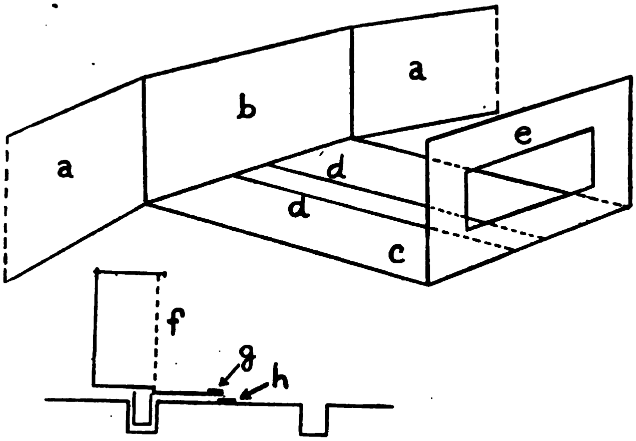

Fig. 2.—Box for examination of stereoscopic parallax: *a, a,* wings, *b,* back; *c,* base; *d, d,* grooves; *e,* front; *f,* thread; *g,* indicator; *h,* tape measure.

One difficulty remains. It is the well known phenomenon, that if, for example, two pins in the median line are looked at, which are behind each other, only one pin can be seen distinctly at the time, while the one in front of the fixed pin is seen in heteronymous double images and the one behind the fixed pin in homonymous double images. In general, if the second point lies before or behind the fixed point in such a way that it comes between both axes of projection or lies on one of these, then always double images are seen. The double images, which form from incitation of two disparate points in the two retinas are located on both sides of the macula in the cyclopean eye, while in all other cases, when disparate points are excited they belong to corresponding halves of the retinas and would be located on the same side of the fovea in the cyclopean eye. However, this cannot be the sole cause, for if the second point is brought out, by lifting from out the plane which goes through the visual axes and the fixed point, the stereoscopic effect appears directly.

The fusion of the retinal images is chiefly connected with the sensation of relief. To produce this sensation it is necessary that the retinal excitation solicit it, determining the cerebral reaction which causes it. This happens during natural seeing, and is particularly apparent when stereoscopic relief is artificially produced. Perhaps in the above mentioned experiment of the three pins we see the double images because the brain does not receive the excitation for corporeal relief.

Stereoscopic vision and normal binocular single vision are not the same. The stereoscopic relief is obtained with virtual images. The distinction between the vision truly subjective, as is the stereoscopic vision and the natural vision, is the noncoincidence or the coincidence of the image of projection with object. When this coincidence is absent, when the image of projection is localized in a spot of space in which the object does not exist and the vision has no more reality, the difference is so little appreciated that all students of stereoscopic vision have identified it with the natural vision of an object.

It is thus the image of projection which makes the reality of the visual sensation. Where it is we have the perception of the object even if it is not there; where it is not we see nothing even if the object is there.

The apparatus of binocular single vision possesses two qualities, which are the cause of the production of stereoscopic relief, namely, the faculty to fuse the exteriorated images of disparate retinal points and the localization of the binocular images where the axes of projection meet, for the axes which start from disparate points, as well as from those which originate in corresponding points.

The identity of the retinas remains the fundamental property of the binocular single vision, but it must be separated from the conception of the horopter. The fusion of double images exteriorated by disparate points is the fundamental cause of the binocular perception of relief. Stereoscopic vision is an abnormal binocular vision, obtained through virtual images with false projection; that is, they do not correspond to the position in space of the objects which give rise to these images. It can be produced without the help of the convergence, which function is indispensable for normal binocular single vision.

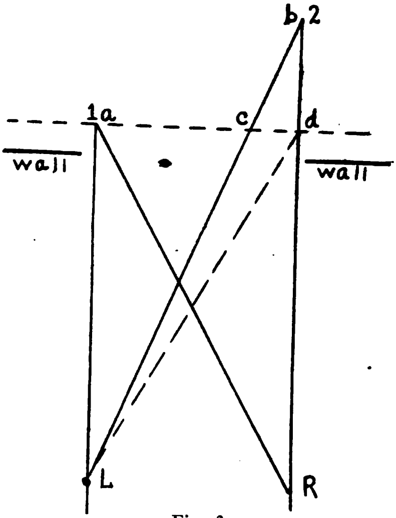

Fig. 3.

Stereoscopic vision implies two distinct actions, namely, the relaxation of the convergence accompanied by a synergetic relaxation of the accommodation, which is an adaptation chiefly of the muscular apparatus and the fusion of disparate retinal points, which produces the sense of relief, and is a sensory property.

The connections which give rise to the production of identical points do not exist over the entire retina; they become less marked on moving away from the fovea. Schoeler found by fusing very simple stereoscopic pictures during instantaneous illumination this region 2.85 mm. in the horizontal meridian at each side of the macula — 6.20 mm. above and 3.10 mm. below it.

In that part of the retina in which there can be question of identity, the faculty to fuse the projections from disparate points is not evenly developed. Ole Bull found that in the horizontal meridian two points of the binocular visual field with a distance of 30 minutes can be fused, while in the vertical meridian this distance cannot exceed 20 minutes.

The horopter is an objective representation of the identity of both retinas — a name and condition for the first time used by François d'Aguilon or Aguilonius. He was a Jesuit priest and published in 1613 at Antwerp his "Opticorum libri six." He defines the horopter as a line drawn through the point of intersection of the optic axes, and parallel to the line joining the centers of the two eyes: the plane of the horopter being a plane passing through the line at right angles to that of the optic axes. He concluded *a priori* that all points which lie in this line are seen singly (*uno loco*), all external to this double *geminis locis*). The mathematical development of the horopter has made its understanding needlessly intricate; it should only facilitate the general comprehension by the exposition of facts. It should not be given too much importance, especially a physiologic significance, which has resulted in a wrong interpretation of the identity of the retinas by giving it an inflexible geometric formula.

The apparatus of binocular single vision has as its chief function the more precise localization in space of the visual sensation; combined herewith is the appreciation of the third dimension, depth and distance. This can be done without any muscular movement, thanks to the different localization in space of the binocular images, according to their projection from corresponding or disparate points, which is the function of the sensory apparatus.

Only for vertical contours do we possess a faculty for distinguishing distances; for horizontal contours we do not possess with motionless view the possibility to discern distance, with the reservation, of course, that of three evenly thick bars, the one which is nearest appears the thickest. At a distance of 2.5 meters this does not have much influence. The depth perception as described is therefore a function of the vertical meridians — of the double eye (Heine).

In this description of facts which lead to an understanding of binocular single vision I have not given anything original. If you can agree to accept the explanation the honor should be due to Wheatstone and Parinaud. Mine has been the pleasure of working out the problem to my own satisfaction.

Habent sua fata libelli — and *autores!* Parinaud has not been appreciated as he should. His dualistic theory of vision has been appropriated by the Germans, and I have found no trace of influence from his two books: "La vision" (1898) and "Stéreoscopie et projection visuelle" (1904), in this country. For me Parinaud possessed the distinct spark of genius; he left his chosen science richer than he found it; he was a noble representative of the true French scientist.

When we now come to examine the sense of depth we find that all tests given in the textbooks are only qualitative ones, no one quantitative test is presented, although it is possible to measure this sense just as accurately as the acuity of vision. A new field still lies fallow.

There are many factors which enter into consideration in our appreciation of solidity. Our appreciation of distance *qua talis* is far below our judgment of reciprocal distance. In the immediate neighborhood accommodation may be of some value, and convergence for a little larger distance, say about 4 meters. However, of the greatest importance is the binocular parallax, the expression of the stimulation of disparate retinal points. It is the difference of the angles under which a distinct external point is distant from the binocular fixed point to the right or left for the right or left eye. Each one of the images projected by both eyes goes out from partly disparate retinal points. Even if the limit is transgressed wherein no double images are formed, we are able, although with less security, to perceive depth by the help of double images. The difference in identity of both retinal images is observed much more accurately as the eye is able to appreciate the distance between two points (form sense). With a basal line of 65 mm. and a binocular parallax of one minute we can judge of the distance of two points, one at a distance of 225 meters, and the other at infinity. No constant relation exists between the observed differences in depth and their physiologic substratum (the binocular parallax), so that a distinct value of the latter should produce a distinct difference in depth, even if all other influences for appreciation of depth are absent. The impression of the size which we receive from an observed distance depends next on the binocular parallax on circumstances which determine our impression of distance.

Another factor in the appreciation of depth is the length of the basal line; the more the eyes are removed from each other, the finer the appreciation of the third dimension, all other factors remaining the same.

Stereoscopic parallax is the apparent displacement for each eye of the objects in different planes, and the deformity of the perspective images which result from it.

On examining patients we find that the sense of depth is very differently developed in man. It can be absent with perfect visual acuity of each eye, or hardly developed. As the appreciation of depth is a faculty developed on the condition of simultaneous vision with alternating macular perception, we shall better understand the different degrees of its acuteness. It can be compared with the appreciation of colors; here we find total absence of color perception, then the appreciation of only two colors, and between this condition and the full appreciation of all colors many different variations. Or it suggests a condition as is found in congenital word blindness, as first described by James Hinshelwood. Word blindness may be due to a congenital defect or deficiency in the brain center or to some pathologic process usually occurring in later life destructive to that center (J. C. Clemesha).

With the stereoscope we can only examine if "fusion" is present, that is, if the patient is able to blend two somewhat unequal pictures, as, for instance, F. and L. to E. But we can only guess as to the presence of appreciation of depth, when we have given two pictures, which by blending should produce this sensation. We cannot prove that the patient sees depth, as also we cannot prove that the patient sees the same color as we by giving the same name.

Hering's fall experiment, considered by nearly all as an infallible test, gives also at the utmost a qualitative appreciation. The principle seems not to be so simple, as on page 877 in the "American Encyclopedia of Ophthalmology" and in J. M. Ball's textbook it is stated that "the patient looks with one eye" through a long tube, etc. Whatever the value of the test may be, we should not forget that it can be positive when the patient cannot fuse in the stereoscope, and that one needs the cooperation of the patient as well as the control of both eyes with each eye separately.

The scientists who explored this field with modern means, Volkmann and others, used three objects (pins and threads) and looked at the displacement of the middle one or at two objects. This simple device can be easily applied; we examine then the stereoscopic parallax. Heine used the three threads, and Brooksbank James made a portable apparatus. He uses two threads or rather wooden pins, puts them in a dark box with a front opening, and asks the patient to look at a distance of 6 meters and to state when he sees the one object back of the other. He and Schoute have published observations. These should be repeated and we should try to find the relationship between visual acuity, length of the basal line and appreciation of the third dimension.

The binocular perception of depth or stereoscopic vision results from the inequality of both retinal images, which are received from a three dimensional object. If these two pictures should cover each other only points in one plane will cover each other exactly, all others will be separated by a distance, which Helmholtz called the stereoscopic parallax. To examine the perception of depth one can put three objects in the same frontal plane and determine how much the middle one must be moved forward or backward to be distinctly perceived in front or behind this plane.

The stereoscopic parallax can also be examined by taking two objects. G. T. Brooksbank James took a box, of which he removed the sides and roof (Fig. 2). In the front wall he makes a good sized opening; the whole inside is made black. In the floor are two longitudinal grooves in which run two carriers to support the test objects; the grooves are placed at equal distances from the margins of the window and there is an interval of 50 mm. between them. At the suggestion of Schoute the test objects are white threads.

For clinical observations the box is placed at a distance of 6 meters from the patient. The box is lighted uniformly, slight movements of the head are without consequence; the accommodation is completely excluded; the perception of the relative position of the threads depends entirely on the binocular parallax.

L and R (Fig. 3) are the nodal points of both eyes. The distance La = Rd = 6 meters; cd is the chord of the angle of the stereoscopic parallax bLd.

Method of Examining.—The patient sits at 6 meters. One eye is occluded by a blinder. He is asked how he sees the two threads, in one level or one closer than the other. He should be told not to guess, but to state what he sees. Then the question is repeated with both eyes open. The head is kept steady.

cd is the stereoscopic parallax:

$$\frac{ac}{aL} = \frac{cd}{bd}. \quad \frac{ad - cd}{6{,}000} = \frac{cd}{bd}.$$

$$cd = \frac{bd \times ad}{6{,}000 - bd}.$$

CONCLUSIONS

1. The term "binocular vision" should not be used for binocular single vision indiscriminately. We must make a sharp distinction between simultaneous vision with alternating macular perception, with absence of fusion in the stereoscope, and binocular single vision.

2. A closer study of the presence of the faculty for appreciation of the third dimension may change somewhat the percentage of hereditary cases in squint; we shall probably find in the ascending line patients who do not squint but in whom this sense for depth is not or imperfectly developed.

3. Its presence or absence may explain the different results after correction of both eyes in anisometropia. It also will explain why some patients with important muscle imbalance have no pathologic symptoms. Operations on the external muscles should not be done unless the "wish" for binocular single vision can be demonstrated. The indication for cosmetic effect is excluded.

4. The appreciation of the third dimension has a high practical value; hence its loss should be compensated for whenever possible; but it is necessary, therefore, to know before the accident that the man had binocular single vision and its degree, so that later the loss can be expressed mathematically. The appreciation of the third dimension is present with different visual acuity, in different degrees. Good visual acuity does not mean also good appreciation of depth.

5. We shall have to reconsider the tests for malingering, as they start mainly from the supposition that binocular single vision has been present before.

6. Every thorough examination should include the examination for binocular single vision.

7. It would be laudable if the section could come to an understanding as to the kind of apparatus to be used.

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THE TREATMENT OF HYPOPYON KERATITIS *

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Of the serious corneal ulcers the most frequent are those due to pneumococci, while next in frequency of occurrence are those due to diplobacilli. The characteristics of the pneumococcus ulcer, or ulcus serpens, are so well known that it is not necessary to discuss them here at length, but it may be well to emphasize certain features. Undoubtedly the most common cause for this type of ulcer is trauma, but there are two other causes that are often not recognized, namely, herpes corneae and glaucoma. Peters,[1] in fact, insists that the peculiar character of ulcus serpens is dependent on a neuropathic basis. This I think is doubtful, but it is probable that in many cases corneal herpes permits the pneumococcus infection to take place. After the infection has become well established the herpetic condition is obscured and so escapes recognition. The course of these cases, however, usually seems to be no different from the frankly traumatic cases. In cases due to glaucoma the failure to recognize the cause may prove disastrous. In many of the eyes that have been removed for perforating ulcer of the cornea and submitted to me for examination I have found deep cupping of the optic disk, although the glaucomatous condition was previously unsuspected. This mistake will less frequently be made if the tension of the affected eye is taken with the finger and the other eye is carefully examined for evidences of glaucoma. The tonometer should not be used on an infected cornea, even after it has appar-

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* From the Massachusetts Charitable Eye and Ear Infirmary.

[1] Peters: Ueber traumatische Hornhauterkrankungen und ihre Beziehungen zum Herpes Corneae, Arch. f. Ophth., 1904, **57**, 93.

ently healed, as the traumatism may have an unfavorable effect.

As a rule an ulcus serpens appears less serious than it really is. This is due to the fact that the leukocytic infiltration is often relatively slight and is most marked at the periphery of the ulcer, leaving the center comparatively clear. The central clear area, however, is really the most severely damaged part of the cornea, for it is almost completely necrotic. The pneumococci are usually most abundant in the infiltrated border of the ulcer because those in the center are cast off with the superficial layers as loss of substance occurs. In rapidly advancing cases, however, before much loss of substance has taken place, I have found the surface layers of the central portion loaded with pneumococci. The center of the ulcer may later appear more opaque owing to the deposition of fibrin and pus cells on Descemet's membrane behind it. This is analogous to thrombus formation on the injured wall of a blood vessel.

Although ulcus serpens is now known to be due to the pneumococcus, yet much bacteriologic work remains to be done in regard to it. The fact that ulcus serpens never occurs in cases of pneumococcus conjunctivitis, while it is not infrequent in cases of dacryocystitis, would seem to show that some special strain or strains of pneumococci are required to produce it. The fact, too, that ulcus serpens is rare in children, although the latter are especially susceptible to penumonia and to pneumococcus conjunctivitis, also seems to point in the same direction. It is possible, on the other hand, that this may be due to the fact that children do not often sustain the kind of injuries most likely to cause ulcus serpens, and that they are seldom affected with corneal herpes or glaucoma. So far as I know, however, no careful bacteriologic investigation of this question has yet been made. In view of the beneficial results of serum treatment obtained by Cole at the Rockefeller Hospital in cases of pneumonia due to certain strains of pneumococci, it is possible that such an investigation would be of value from the standpoint of treatment of corneal ulcers.

The diplobacillus ulcer differs considerably in its clinical appearance from ulcus serpens, but if not properly treated is fully as destructive to sight. There are several varieties of diplobacilli that may cause corneal ulcers, the most common being the Morax-Axenfeld. All such ulcers seem to have about the same clinical characteristics, so that for practical purposes the diplobacilli may be identified with sufficient accuracy by the examination of smears. It has been stated that it is impossible to differentiate by clinical appearances alone between pneumococcus and diplobacillus ulcers, but this is not in accord with my own experience. Perhaps the most striking feature of the diplobacillus ulcer is the relatively slight general reaction of the eye compared to the extent of the ulcer. This is manifested especially by the size of the hypopyon, which is relatively very small. The ulcer itself is more uniform in appearance than an ulcus serpens, the marginal infiltrate being less marked and the whole ulcer having a gelatinous appearance, due to plastic exudate.

The treatment of hypopyon keratitis has hitherto been highly unsatisfactory, judging by the fact that out of all the diverse methods of treatment no single one has been generally adopted. It would be impracticable here to discuss each of these methods in detail, and I have therefore attempted to classify them as follows:

Symptomatic Treatment.—This includes the use of an occlusive bandage, hot applications, and atropin to combat the iritis. The use of various nonirritating ointments may also be included under this head, since, judging by the ineffectiveness of still stronger antiseptics, their only value is to act as lubricants. Ethylmorphin hydrochlorid (dionin) is also frequently used, and some surgeons employ miotics instead of atropin. This method of treatment undoubtedly yields a fair percentage of relatively good results, a fact that is apt to be lost sight of when estimating the value of other methods.

Serum Therapy.—The antipneumococcus serum of Roemer has not yielded the results anticipated, and has therefore never come into general use. As already pointed out, however, in view of the results obtained in cases of pneumonia at the Rockefeller Hospital, there is still a possibility that an immune serum may be developed that will prove effective in corneal ulcers due to certain strains of pneumococci.

Vaccine Therapy.—If vaccine therapy is under any condition effective against pneumococci, it should be especially valuable in cases of ulcus serpens, for here we have a relatively minute localized focus insufficient to cause any appreciable systemic reaction. Nevertheless, no conclusive evidence has been brought forth that vaccines are of the slightest benefit in cases of ulcus serpens. Recently much interest has been shown in the nonspecific treatment of infectious diseases by injections of other foreign proteins, but I am not aware that it has yet been tried in cases of corneal ulcer.

Chemotherapy.—As regards the treatment of localized infections in general, the ideal germicide, of course, would be one which destroyed the micro-organisms without seriously injuring the tissues. In 1907, with E. K. Ellis,[2] I made experiments with a large number of antiseptics claimed to be noninjurious to the tissues, and found that in every case their germicidal activity was destroyed by serum. This explained at once their ineffectiveness against infections as well as their nonirritating qualities. It seems to me that it is altogether unlikely that any chemical substance of simple structure will be found to fulfil the ideal requirements. In any case, dilute solution of the germicide and prolonged exposure to its action would probably be necessary for differential effects as between the organisms and tissues. Thus far, no germicide fulfilling the foregoing requirements has been brought forward with the possible exception of optochin.

Ethyl-Hydrocuprein (*Optochin*).—This was introduced by Morgenroth as a specific germicide against the pneumococcus. It seems, however, to have proved a disappointment in the treatment of pneumonia, owing to the fact that it cannot safely be given in doses sufficiently large to be effective. It has also been used as a local application in the treatment of ulcus serpens, and almost all the reports of cases so treated have been highly favorable. When added to serum, the hydrochlorid is immediately and abundantly precipitated, so that it is evident that only a minute quantity could penetrate inflamed tissues. It is stated, however, that enough remains in solution to give a certain amount of germicidal effect. It seemed improbable to me that this could be sufficient to be of service in the treatment of ulcus serpens, and I have therefore waited for more conclusive evidence before personally giving optochin a trial. In the meantime I have noted its action in a few cases of my colleagues in which it has been highly ineffective. It is noteworthy that even those reporting favorable results admit failures in certain cases. These are explained by assuming that the organisms develop tolerance toward the drug. I suspect, however, that the real difficulty is that the germicide cannot reach the organisms when the cornea is deeply infected. This is suggested also by the fact that many treatments are necessary, whereas if the germicide actually reaches the organisms in effective concentration, as supposed to be the case, it should be possible to sterilize the ulcer in one or two vigorous treatments.

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[2] Verhoeff, F. H., and Ellis, E. K.: The Bactericidal Values of Some Widely Advertised Antiseptics, The Journal A. M. A., June 29, 1907, p. 2175.

Organic Silver Salts.—The best known of these are argyrol and protargol, but many others have been brought forward. Pitzman[3] has pointed out that their germicidal properties depend entirely on the amount of uncombined silver salt they contain. It is obvious that their irritating properties depend on this also. Thus argyrol contains a very small amount of uncombined silver salt and hence is almost nonirritating and nongermicidal, while protargol, which contains a relatively high proportion, is correspondingly more highly germicidal and also more irritating in solutions of the same concentration. So far as germicidal activity goes, the large amount of combined silver in argyrol is wasted. In other words, if solutions of each of the various organic silver compounds were made in such concentrations as to have the same irritating properties, they would each have practically the same germicidal powers. In 1906 I showed that the germicidal properties of argyrol and protargol are destroyed by serum, so that it is impossible for them to kill bacteria within inflamed tissues even if they reach the organisms.[4] Although it seems certain, therefore, that they are valueless in the treatment of corneal ulcers, their use for this purpose has not even yet been generally abandoned.

Tincture of Iodin.—This has been highly rceommended for the treatment of corneal ulcers, but I fail to see how it can be of service except in the most superficial infections. While it is highly germicidal to bacteria immersed in it, as ordinarily applied to corneal ulcers, it cannot penetrate the tissues effectively. When it comes in contact with moist surfaces the alcohol is diluted and the iodin precipitated, or the alcohol precipitates the albuminous bodies encountered and is thus checked in its penetration. In this connection the following experiment seems to be of considerable significance: I applied tincture of iodin to a large colony of staphylococci growing on coagulated blood serum, allowing the solution to act for over two minutes. On then making a culture from the colony, I obtained an abundant growth. Unless, therefore, the solution is applied sufficiently long and in sufficient abundance as markedly to injure the tissues, no important germicidal action can be expected from it. This conclusion, I may say also, is in accord with my practical experience.

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[3] Pitzman: The Antiseptic and Germicidal Properties of the Silver Salts and Preparations, Am. Jour. Ophth., 1912, **29**, 1.

[4] Verhoeff, F. H.: A Further Note on the Antiseptic Properties of Sodium Aurate, Correspondence, The Journal A. M. A., May 12, 1916, p. 1462.

Zinc Sulphate.—Axenfeld[5] states that he has never failed to check the progress of a diplobacillus ulcer of the cornea by means of zinc sulphate. He uses strong solutions applied directly to the ulcer and weak solutions instilled into the conjunctival sac. A few observers report unsuccessful results with this treatment in severe cases. In laboratory tests zinc sulphate is said to have but slight germicidal action on diplobacilli, so that its therapeutic value is probably dependent on an inhibitory effect.

Anilin Dyes.—Pyoktanin (methyl violet) and methylene blue have been used in the treatment of corneal ulcers, but without marked success. Basic fuchsin and gentian violet have in recent years been advocated as effective nonirritating germicides, but experiments made by me go to show that their germicidal action is too feeble to promise any success in the treatment of corneal ulcers. Thus in 1 per cent. solutions I found that neither of these dyes would destroy the *Staphylococcus aureus* with exposure of over an hour. A saturated aqueous solution of methylene blue was not destructive to this organism after an exposure of four and one half hours.

Ion Therapy.—The attempt to sterilize corneal ulcers by treating them with solutions ionized by an electric current seems to me irrational, for in this way the antiseptics are dissociated into simpler elements whose action on the bacteria and the tissues must be still less differential than the original solutions.

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[5] Axenfeld: Bacteriology of the Eye, translated by MacNab, New York, 1908, p. 301.

Thermotherapy.—The effectiveness of the thermocautery in the treatment of corneal ulcers has been well demonstrated by actual experience. The objection to its use is that so much tissue must be destroyed or injured in order to insure destruction of the organisms that excessive scarring results. Several attempts have been made to obviate this difficulty. Bourgeois[6] employed a blast of hot air, such as is used by dentists; Weekers[7] held the cautery point at a distance from the ulcer, while Wessely[8] employed a tube with a blunted point heated by steam. More recently Shahan[9] has made a careful experimental investigation along this line, and has devised an instrument by means of which he can accurately control the temperature to which the cornea is heated. He found, however, that with the moderate temperatures and relatively long exposures with which he worked, it was impossible to destroy bacteria within the cornea without severely injuring the corneal tissue.

Prince[10] has advocated what he terms the pasteurization of corneal ulcers. A conical shaped piece of copper is heated to a red heat and then held close to the ulcer until it cools. The treatment is given once or twice daily. Prince contends that the organisms are checked in their growth, thus allowing the natural defenses of the body better opportunity to cope with them. I have tried Prince's method both clinically and experimentally, and have reluctantly concluded that it is of little if any value. It was used in five clinical cases of ulcus serpens, all of a severe type. In two of these cases perforation occurred; in one, Guthrie-Saemisch section was required, and two came to enucleation. Experimentally I tested out the method by injecting staphylococci into each cornea of a rabbit and then "pasteurizing" one of them. I found that when care was taken to inject about the same number of organisms in each eye, the resulting abscesses were practically identical in size.

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[6] Bourgeois: Nouvelles considérations sur le traitement des ulcères infectieux de la cornée, Ann. d'ocul., 1899, **122**, 55; Le chauffage des ulcères infectieux de la cornée, ibid., 1911, **145**, 273.

[7] Weekers: Nouveau traitement des ulcères serpigineux de la cornée par le chauffage, Bull. de la Soc. belge d'ophth., 1910, No. 28, p. 70.

[8] Wessely: Zur Behandlung des Ulcus serpens, Ophth. Cong. Heidelberg, 1912, p. 339.

[9] Shahan: Effects of Heat on the Eye, The Journal A. M. A., Aug. 5, 1916, p. 414.

[10] Prince: Pasteurization in the Treatment of Corneal Ulcers, Ophth. Rec., 1916, **25**, 177.

Working with Dr. C. E. Hill, I have also investigated the possibility, suggested previously by Shahan, that intense heat briefly applied might be more injurious to bacteria than to the cornea. It seemed to me that radiant heat offered the greatest possibility of success, since, owing to the transparency of the normal cornea, there would be a selective action on an ulcer owing to the absorption of the rays by the infiltrate, and since also, working with Bell,[11] I had found that the effect of radiant heat was greatest in the deepest layers of the cornea. We therefore made use of a carbon arc and lens system which delivered enough radiant heat at the focus to ignite a match almost instantly. The experiments were made by injecting staphylococci into one cornea of a rabbit and then exposing each eye in turn to the light for the same length of time, which was varied in different experiments. We found that even when the control cornea was severely injured by the heat, an abscess nevertheless developed in the infected cornea. These experiments seemed so conclusive that it appeared useless to proceed further. If they had resulted more favorably, it was our intention to standardize the apparatus and also to attempt to devise some method for protecting the iris and fundus of the eye from injury.

Phototherapy.—Hertel[12] in 1903, and again in 1907, brought forward what he regarded as conclusive evidence of the value of ultraviolet light in the treatment of corneal ulcers. I have elsewhere discussed Hertel's experiments and have pointed out that none of them were conclusive. In addition I have recorded a series of experiments[13] which prove that it is impossible to destroy bacteria within the cornea by means of ultraviolet light without severely injuring the cornea. In most of these experiments the cornea was exposed to the light immediately after it had been injected with bacteria, that is, while it was still transparent. If under these conditions the bacteria could not be killed without undue injury to the cornea, it is obvious that it would be futile to attempt to kill them in a cornea infiltrated with pus cells and so made practically impassable to germicidal rays. In fact, by the use of suitable screens, I found that the relatively long ultraviolet waves, the only ones that are able to penetrate the cornea, are much less injurious to the bacteria than to the cornea.

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[11] Verhoeff, F. H., and Bell, Louis: The Pathological Effects of Radiant Energy on the Eye, Proc. Am. Acad. Arts and Sc., 1916, **51**, 692.

[12] Hertel: Experimentelles über ultraviolettes Licht, Ber. u. d. 31 Vers. d. ophth. Ges., Heidelberg, 1903, p. 144; Experimentelles und Klinisches über die Anwendung lokaler Lichttherapie bei Erkrankungen des Bulbus, Arch. f. Ophth., 1907, p. 275.

[13] Verhoeff, F. H.: Ultraviolet Light as a Germicidal Agent, The Journal A. M. A., March 7, 1914, p. 762.

Cauterization.—Various chemical caustics have been advocated in the treatment of corneal ulcers, and probably any of them will check the ulcerative process if properly used; but the thermocautery seems to be generally preferred. Of the chemical caustics, pure phenol (carbolic acid) is probably as good as any, if not better. It has been shown experimentally by Guillery[14] that mineral acids should be avoided, owing to the danger of injuring the lens. The chief objection to the use of caustics of any kind is the same as that which applies to the thermocautery, that is, the excessive scarring which results.

Subconjunctival injections of irritating solutions for the purpose of causing severe reactions and thus combating the infection have been highly recommended in the treatment of corneal ulcers. Fuchs[15] stated that he regarded this method of value in early cases but of no service in advanced cases. I myself have found other treatment so effective in early cases that it has seemed unnecessary for me to give this painful method a trial.

Operative Treatment.—Stephenson[16] has pointed out that priority for the operation of incising corneal ulcers belongs to Guthrie, who performed the operation twenty-seven years before Saemisch. The beneficial effect of this operation is generally so great as well as prompt that there is no question as to its effectiveness. The explanation of its effect is probably that it reduces the pressure on the cornea and allows drainage to take place from the cut surfaces, while at the same time it causes the ulcer to be continually irrigated by fluid from the anterior chamber. This fluid is no longer ordinary aqueous, but owing to the low intra-ocular pressure as well as the inflammatory reaction, it is almost pure serum and hence richly contains the bactericidal properties of the blood. In rare cases, however, this operation fails and the ulceration continues, or intra-ocular infection takes place through the incision. Probably in these cases either the organisms are unusually virulent or the patient's serum is lacking in immune substances.

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[14] Guillery: Hornhautverätzung durch Säuren und ihre Behandlung, Arch. f. Augenh., 1909, **63**, 258.

[15] Personal communication to the author.

[16] Stephenson: Priority; Guthrie or Saemisch Operation for Hypopyon Keratitis, Ophthalmoscope, 1910, p. 266.

In spite of the remarkable results usually following the Guthrie-Saemisch operation, it is generally employed only as a last resort, for although it may put a stop to the ulcerative process, the condition finally resulting is apt to be far from desirable. Almost always there is anterior synechia with its attendant dangers of secondary glaucoma and sympathetic uveitis, while the irregular astigmatism resulting from the scar is apt to be of an extreme degree.

Keratectomy.—Foroni[17] reports exceptionally good results from dissecting away the superficial layers of the cornea in the ulcerated area, curetting the wound and irrigating with a 1: 1,000 solution of mercuric cyanid. That the results of this treatment are not all that could be desired, however, is shown by the fact that he finds it necessary in some cases to perforate the cornea in its periphery with the galvano-cautery. I have never tried this method, but it seems to me unnecessarily severe.

Conjunctival Flaps.—The placing of a conjunctival flap over a corneal ulcer has been strongly recommended by Kuhnt and others as an effective method of treatment. In the few cases in which I myself have tried this procedure, the flap has not remained in position long enough to be of any service. Possibly my technic has been at fault here.

Author's Method.—With the limited number of cases at my command, it has seemed to me better to continue a method that was giving good results, to find out its exact limitations, and to attempt to improve it, rather than to change continually from one method to another and thus reach no definite conclusions. In this way, during the past three years, I have worked out a method of treating corneal ulcers that has given results more satisfactory than has any other method I have employed or seen used. I am far from regarding the method, however, as the final solution of the problem.

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[17] Foroni: Keratektomie, Arch. f Augenh., 1915, 78, 279.

The patient is placed in bed, the affected eye thoroughly cocainized, and a speculum inserted. He is then told to look at various points on the ceiling until a position is found at which the ulcer is directly upward. This position must be maintained throughout the treatment, but the patient seldom finds any difficulty in keeping his eye sufficiently steady. Occasionally it has been necessary for him to fix his other eye on the finger of an assistant. With a Beer's knife, incisions are now made in the ulcer thus: The back of the knife is held toward the cornea and the point entered slantingly into the margin of the ulcer. The knife is then pushed through the middle of the ulcer to the opposite margin, care being taken to make the incision as deep as possible without entering the anterior chamber. It will be found that, owing to the slanting position of the knife, Descemet's membrane is pushed away from the point so that the incision may be carried down almost if not quite to this membrane without danger. The point of the knife is now entered in the center of the incision just made, and a radial incision perpendicular to the latter carried to the margin of the ulcer. A similar incision is then made in the opposite direction, so that the final result is a crucial incision. In the case of large ulcers, several additional incisions should be made, starting each time at the center. With the point of the knife the infiltrated border of the ulcer is now superficially curetted, and the material obtained used for the bacteriologic examination. After this, the entire surface of the cornea around the ulcer is dried by touching it with small dry swabs of sterile absorbent cotton.

The ulcer is now ready for treatment with the germicide, a highly concentrated Lugol's solution: iodin, 25; potassium iodid, 50; water, 100. This is applied by means of cotton-tipped tooth picks, and the application should be limited to the ulcer itself, as the solution will quickly injure the epithelium. Owing to the cornea's being dry, the solution has no tendency to spread beyond the ulcer. After the entire area of the ulcer has been moistened, additional solution is added

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until there is an actual puddle on the ulcer. This is allowed to remain five minutes, when it is quickly flushed out of the conjunctival sac by a jet of boric acid solution. A rubber bulb filled with boric acid solution should be in constant readiness for this purpose, for should the patient move his eye abruptly and cause the Lugol's solution to flow over the cornea, it is necessary to wash it away at once. If this should happen before the five minutes have elapsed, the cornea should be dried again and the Lugol's solution reapplied. The treatment is absolutely painless.

In cases of very small ulcers, the Lugol's solution is applied without making the incisions described. In deciding whether or not to make the incisions, I do not depend entirely on the size of the ulcer, however, but also on the rapidity of its progress and the amount of general ocular reaction, as evidenced particularly by the size of the hypopyon. In active cases, even when the ulcer is small, it is probable that the organisms have become disseminated for a considerable distance from the ulcer proper and hence may not be reached by the germicide unless the incisions are first made. When there is doubt, the incisions should always be made, as they do not noticeably increase the opacity left by the ulcer. In fact, as the ulcer heals, all traces of the incisions disappear.

In cases of rapidly progressing ulcers of large size, with large hypopyon, after the foregoing treatment has been completed, I make a small puncture through the center of the ulcer with the Beer's knife, and evacuate the aqueous. This puncture is not large enough to evacuate the hypopyon, and I believe it advantageous for the latter to remain. It holds both the iris and lens away from the opening, and thus prevents anterior synechia and injury to the lens. I have never seen any harm result from this central puncture, and I now always make it unless I am absolutely certain it is unnecessary. In cases of suspected glaucoma, it should never be omitted. Its chief disadvantage is that it causes more or less pain.

The after-treatment of these cases consists in keeping the patient in bed with both eyes bandaged, the use of White's mercuric chlorid ointment as a lubricant, and in the instillation of atropin to keep the pupil open. The beneficial effects of the iodin treatment do not become apparent until after forty-eight hours, when the ulcer appears cleaner, the hypopyon smaller, and the eye becomes much more comfortable. In case the central puncture was made, the longer the anterior chamber remains empty the better. If no improvement is noted at the end of seventy-two hours, and the anterior chamber has become reestablished, the treatment should be repeated.

It may be of interest to give the reasons that led me to adopt this method of treatment. Although it was evident that we possessed no germicide that would destroy bacteria in the cornea without injury to the cornea itself, it seemed to me that some of the germicides must be far less injurious than others. Moreover, since the cornea was already severely injured in the ulcerated area wherein the bacteria chiefly occurred, it seemed that a certain amount of additional injury would make relatively slight difference as regards the visual results. It occurred to me, therefore, that Lugol's solution, which was known to be a powerful germicide, might answer my purpose. I found that a freshly prepared solution even in as high dilution as 1:2,000 (iodin, 1; potassium iodid, 2; water, 2,000) would destroy the *Staphylococcus aureus* in less than one minute. I also found, however, that when mixed with an equal volume of ascitic fluid, a solution of 2:1,000 would not kill this organism in twenty-four hours. It was evident, therefore, that dilute solutions would be useless, since their germicidal activity would be destroyed as they permeated the tissue, and solutions sufficiently strong to overcome the neutralizing effect of the tissue fluid would be necessary. In this connection I found by experiments on rabbits that while strong solutions promptly killed the corneal corpuscles, they had remarkably little effect on the corneal stroma. For instance, a small amount of a 1 per cent. solution could be injected directly into the cornea without causing a permanent opacity. Evidently new corneal corpuscles made their way in from the periphery, and the original condition of the cornea was restored. Since in corneal ulcers the corneal corpuscles are already largely destroyed by the bacterial toxins, it appeared likely that strong Lugol's solution would do no additional harm except so far as it destroyed a greater or less number of corpuscles at the periphery of the ulcer. On the other hand, it was found that if an area about 5 mm. in diameter was injected with the 1 per cent. solution, it caused, owing to its prolonged action, softening of the corneal stroma and a permanent opacity.

It is unfortunately not possible to produce in animals progressive corneal ulcers similar to those caused in man by pneumococci. I was compelled, therefore, to test the value of Lugol's solution by actual trial in human cases. At the outset I employed a 2 per cent. solution and applied it by placing a glass tube over the ulcer and filling the tube with the solution. This method seemed effective, but was difficult of application. I then increased the strength of the solution to 5 per cent. and used the method of making a puddle on the ulcer as mentioned above. In cases of small ulcers this was uniformly successful, but in cases of larger ulcers it sometimes happened that the process would start up again at one point or another, thus indicating that bacteria in the comparatively normal cornea had not been reached by the germicide. I then adopted the plan of making incisions in the ulcer for the twofold purpose of allowing the germicide to permeate the tissue more freely and of permitting drainage afterward. At the same time the strength of the Lugol's solution was increased to 25 per cent. Even with this powerful solution applied for five minutes, there was an occasional case in which evidently not all the bacteria were not killed. In fact, judging by the amount of discoloration of the tissues, it was clear that in no case did the solution penetrate far into the normal corneal tissue. For rapidly progressing cases, therefore, in which it was probable that the organisms had become disseminated far into the cornea away from the ulcer, the plan was adopted of making a central puncture in the ulcer to obtain as far as possible the additional advantage of the Guthrie-Saemisch operation without its disadvantages.

Altogether I have treated forty-two cases of corneal ulcer with hypopyon by this method. These cases were unselected except to the extent that only such cases were treated in this way as were regarded as sufficiently serious to require admission to the hospital. Bacteriologic examinations, which were made in almost every case, showed the ulcers to be due either to pneumococci or diplobacilli.

In twenty-one cases the ulcer was small, from 1.5 to about 4 mm. in diameter, and the process was checked in every case. In these cases the visual acuity at the time of discharge from the hospital was $^{20}/_{70}$ or better in seven cases, $^{20}/_{100}$ in five cases, $^{20}/_{200}$ in six cases, and $^{12}/_{200}$ in two cases. In one case the acuity was equal only to the counting of fingers at 8 feet; but this was due to an older scar. In eight cases the ulcer was of moderate size, but was sufficient to reduce the visual acuity to the perception of light or the counting of fingers. Here the process was also checked in every case, but the resulting visual acuity was of course not great at the time of discharge, ranging from the counting of fingers at from 1½ to 8 feet. In thirteen cases the ulcer was very large, involving from one-half to two-thirds or more of the corneal surface. Here the process was checked in eight cases, but the visual acuity obtained was only equal to the perception of light or shadows. In five cases the process was not checked, and in three of these enucleation was performed. No doubt in some of the cases the vasual acuity could later have been improved by optical iridectomy.

The average age of the patients with small ulcers was 39 years, while that of the patients with larger ulcers was 50 years. It would seem, therefore, that older persons allow the ulcerative process to gain greater headway before applying for treatment. This, I think, is due in part at least to the lessened sensibility of the cornea and the weaker mentality of the older persons.

In one of these cases the ulcer was associated with dacryocystitis. In twenty-two cases there was a definite history of recent trauma. Glaucoma was noted in one case, but may have been overlooked in others. Diplobacilli were found in six cases. In each of these the process was checked, except in one in which three-fourths of the corneal surface was involved at the time of treatment. Owing to illness, this patient was not treated by me personally.

Judging by my results, as well as by those of some of my colleagues who have also tried this method of treatment, I feel safe in saying that it will stop the progress of any corneal ulcer of small size and leave a minimal scar. In cases of ulcers of moderate size the process will also almost always be checked by it, but in cases of very large ulcers failures will often occur, owing to the fact that the germicide cannot reach all the bacteria. In the latter cases, however, so much of the cornea has already been involved that little is to be gained by checking the ulcerative process. It is important, therefore, in the case of any ulcer to apply the treatment as soon as the patient presents himself. In hospital practice, to save unnecessary delay, the treatment should be carried out in the outpatient department before the patient has been admitted to the wards.

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FURTHER STUDY OF THE EFFECTS OF HEAT ON THE EYE *

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In this work and in the work[1] reported at the 1916 session of the American Medical Association, the method of applying heat to the cornea has been one of direct conduction by means of hot metal placed in contact with the cornea. Methods of radiation by holding hot objects near the eye, by convection, through hot air or steam, etc., have been unsatisfactory because of the difficulties in exact control both as to intensity and as to quantity.

The difference between success and failure in applying heat in such grave conditions as serpiginous ulcer of the cornea is measured by only a few Fahrenheit degrees, as will be shown in the following experiments and case reports. Moreover, different materials have different degrees of heat conductivity, just as they do of electric conductivity. For an exact definition, therefore, it is necessary to state the intensity as indicated by the thermometer or thermocouple, and the material used for conducting the heat. In all these experiments and cases the material used was brass plated with nickel.

An experiment will make clear the need of stating the material used for conduction. A mass of nickel-plated brass (the thermophor applicator described at the 1916 session) was heated to 150 F. and applied to the cornea of a rabbit's eye for one minute. The epithelium was destroyed over an area somewhat greater than the surface placed in contact with the cornea.

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[1] Shahan, W. E.: Effects of Heat on the Eye, The Journal A. M. A., Aug. 5, 1916, p. 414.

in diameter stains with fluorescein. Washed with physiologic sodium chlorid solution.

July 15: O. D., ulcer quiet. No discharge, no hypopyon. O. S., ulcer very active, much discharge, no hypopyon.

July 17: O. D., profuse growth on culture, taken before heating. No growth on culture taken after heating. Eye quiet. Epithelium completely replaced. Thin gray spot on site of ulcer. O. S., much discharge, cornea clouded. Deep ulcer. Area 5 by 8 mm. stains with fluorescein.

July 21: O. D., entirely quiet. Gray central area becoming thinner. O. S., active ulceration. Pupil filled with a membrane. Whole cornea opalescent. Considerable discharge through the epithelium, which has covered ulcer so that fluorescein does not stain.

July 24: O. D., entirely quiet. O. S., severely inflamed. Vessels extend into cornea about 4 mm. from all parts of limbus. Center of ulcer stains with fluorescein.

July 27: O. D., entirely quiet. O. S., still severely inflamed. Vessels extend as a dense red zone 5 mm. into cornea from all parts of limbus.

July 31: O. D., entirely quiet. O. S., site of ulcer yellow, broken down and excavated. Whole cornea up to margins of ulcer filled with a dense network of blood vessels.

August 3: O. D., entirely quiet. O. S., site of ulcer organized. Still yellow deep within substantia propria. Hyphemia.

September 29: O. D., thin gray area at center of cornea. No iris changes. O. S., vessels in cornea all atrophied. Small gray area center of cornea. Yellowish deposit along lower part of cornea. Some clouding anterior capsule. Firm posterior synechiae.

This was repeated on rabbits with variations, sometimes with, sometimes without hypopyon, until it seemed reasonably certain that 152 F. applied for one minute was sufficient to stop the ulcerative process.

It now became desirable to know how much damage this amount of heat did when applied to a normal eye. This was applied to various eyes, and it was found in general that there was complete destruction of the epithelium over an area somewhat larger than the point used. With a 5 mm. point, for instance, there was an area 5 by 6 mm. of denudation. The surface of the cornea was clouded so that often the iris was not visible through it. The epithelium replaced itself in four or five days, and the clouding slowly diminished. A rabbit with O. S. heated so, July 27, 1916, now (Jan. 30, 1917) has a faint nebula at the site of application. The nebula is difficult to see without oblique illumination and the aid of a magnifying glass.

It would seem, therefore, that this method of thermotherapy offered much in the deep treatment of pneumococcus infections, and it was felt that the time was ripe for trial on human eyes when opportunity offered.

To date the following patients have been treated:

Case 1.—Coal miner, aged 39, consulted Dr. E. C. Spitze, East St. Louis, Dec. 17, 1916. A foreign body was removed from near the inner limbus. There were two small foci of infection at the site of the foreign body. Ulcers were cauterized with saturated phenol iodin solution. The foci coalesced and the ulcer slowly increased in size despite active daily treatment. Dec. 28, 1916, Dr. Spitze brought the patient to me for trial of heat treatment. The ulcer then bordered the limbus and extended about 3 mm. out into the cornea. Trial of methylene blue and 1 per cent. silver nitrate solution to the walls of the ulcer was advised. Dr. Spitze did this and also made subconjunctival injection of 20 mm. of 1:3,000 mercuric chlorid solution. The patient was now in the hospital. The ulcer was steadily growing worse.

Jan. 8, 1917: Dr. Spitze again sent the patient to me. The ulcer now extended 5 mm. along the limbus and 4 mm. into the cornea. There was a dark border where the silver nitrate was applied, and beyond this a yellow zone of virulent infection. Hypopyon was 1 mm. high. The patient complained much of pain. Heat was applied at from 150 to 152 F. with a 5 mm. applicator for one and one-fourth minutes to the ulcer under thorough anesthetization with cocain, 5 per cent. in suprarenal extract, 1:1,000. The application appeared to cause but little pain. After the application the yellowish color was changed to a grayish hue. The epithelium was destroyed over an area extending 1 mm. beyond the margin of the ulcer.

January 9: The patient spent a more comfortable night; the ulcer was quieter and grayish in appearance. The hypopyon was unchanged. Subsequently there was very little pain. The hypopyon disappeared and the ulcer became quieter until January 13, when there was a slight renewal of activity deep within the substantia propria in the border of the ulcer nearest the center of the cornea. There was a slight hypopyon with renewal of pain. Heat at from 150 to 152 F. was then applied for one minute with a 5 mm. applicator. The edge of the applicator was pressed with special firmness against the most active part of the ulcer. There was rather extensive coagulation of the new epithelium that had grown over the site of the ulcer since the first application of heat.

January 15: The ulcer was quiet. There was no discharge. The hypopyon was gone. There had been no pain since three or four hours after the application. Most of the heated area was still bare of epithelium.

January 20: The patient had been slightly uncomfortable for the last two days. There was no discharge. There was a faint diffuse staining with fluorescein along the edge of the ulcer nearest the center of the cornea. There was no hypopyon. A slight gray infiltration along the central and lower edge of the site of the ulcer may have indicated some pneumococcic activity deep within the substantia propria. Atropin and cocain (oil solution) was used. It was decided to wait another day before applying heat.

January 21: The patient was comfortable last night. The gray infiltration appeared to be breaking up into isolated foci. There was no hypopyon. There was no staining with fluorescein. Coddington lens (1 inch focus) revealed the site of the ulcer nearly surrounded by a narrow bulla. Atropin and cocain were used.

January 24: The eye was quiet. The site of the ulcer was filling in. There had been a severe iritis along with the ulcer. There were numerous posterior synechiae and some deposit of the anterior capsule. V. = 3/60. The ulcer did not reach the center of the cornea, and if the deposit on the anterior capsule clears up good vision should be obtained. This patient was seen daily either by Dr. Spitze or myself, and is now in Dr. Spitze's charge. Treatment was complicated by a suppurative postethmoidal and sphenoidal sinusitis. These conditions were cared for by Dr. Arbuckle.

February 10: Dr. Spitze telephones that there has been no renewal of the ulcerative process. The cornea has cleared up and the globe is slowly quieting down.

Case 2.—Man, aged 56, appeared in Dr. William F. Hardy's service at Washington University Clinic, Jan. 16, 1917, with a corneal ulcer 6 by 8 mm. staining brightly with fluorescein. The eye was blind as the result of an old injury. It was treated with silver nitrate, 0.5 per cent., and atropin. It was bandaged.

January 17: All the symptoms had increased. The treatment was the same.

January 18: A very profuse mucopurulent discharge was soaking the bandage and gumming up the lids and lashes. The patient had had much pain last night. There was moderate hypopyon. The ulcer was larger. Cultures revealed probably pneumococci submerged in staphylococci. With the thermophor, heat was applied at from 150 to 152 F. for one minute to the upper half, and one minute to the lower half of the ulcer with a 5 mm. point. The whole surface of the ulcer was made somewhat gray by the heat.

January 19: The patient complained of pain in the head and the left jaw last night. There was much less discharge. The ulcer was cleaner. There was not much pain in the eye. The hypopyon was about the same as yesterday. Silver nitrate, 0.2 per cent., and atropin were used. A bandage was applied.

January 20: The patient passed a comfortable night. There was very little discharge. The ulcer was quiet. The patient had the notion that the treatment (heat) had affected the other eye. No physical evidence of this was found. He could not be rid of the notion. Treatment was the same as before.

January 22: The eye had not been dressed for two days. The dressing was dry. The "eye felt fine." The hypopyon was gone. There was a small active area at the upper margin of the ulcer. This should have had heat treatment with a small crescentic applicator. The patient refused to permit this. Treatment was the same.

January 23: The patient had much pain last night. There was a moderate discharge. The active area noted yesterday was extending rapidly downward over the former site of the ulcer. The patient refused heat. He was turned over to an assistant for routine treatment. He disappeared from the clinic. This eye might have been saved either by a higher or more extensive initial application, or by repeating the application over the small area of exacerbation as soon as it appeared

Case 3.—A coal miner, aged 46, was referred to me by Dr. Spitze for heat treatment, and has since been cared for by us jointly.

January 18: The patient was struck in the right eye five days ago by a piece of coal. There was an ulcer at the center of the cornea 5 mm. in diameter. Hypopyon was 1 mm. high. Cultures and smear revealed pneumococci. There was very marked chemosis. The bulbar conjunctiva overhung and lay on the cornea for about 1 mm.

In this case the serious mistake of explaining the working of the thermophor to other physicians in the presence of the patient was made. The applicator was felt by these physicians and the audible comment on its hotness made. As a result the patient was nervous and apprehensive, expecting his eye to be burnt. Heat, from 150 to 152 F., was applied for one minute somewhat intermittently. The patient did not hold his eye still. This was done by artificial light, and slight changes in the hue of ulcer could not be made out.

January 19: Dr. Spitze reported that the patient had very little pain last night.

January 20: The ulcer was much worse and was spreading in all directions. The hypopyon was larger. The ulcer was too large to be covered by a 5 mm. thermophor point. Heat, from 150 to 152 F., was applied to the upper temporal surface of the ulcer for one minute and also to the lower nasal surface for one minute. Continuous applications were made. The patient exhibited some signs of pain.

January 21: Dr. Spitze reported the ulcer clean and much better.

January 22: The eye had not been dressed for about twenty hours. There was little complaint of pain. The ulcer was clean. The bandage was dry. There was no discharge. There was a small area of activity at the upper margin and another at the temporal margin of the ulcer. Heat, from 150 to 152 F., was applied to each of these for one minute with a 2 mm. applicator. They were washed with physiologic sodium chlorid solution. Atropin and cocain (oil) solution was used.

January 23: The patient had considerable pain, especially in the head, last night. The ulcer was generally clean. The active area at the upper margin of the ulcer was still somewhat active. The active area at the temporal side was quiet. The eye "felt fine" this morning. The hypopyon was smaller.

January 24: The conjunctiva at the upper limbus overhung the cornea and extended downward on it for 2 mm. Beneath this fold and sharply defined by it was a very active deep area of infection. All the rest of the cornea was quiet and translucent, allowing all parts of the iris and pupil to be seen. This focus emphasized the previous statement that pneumococci are most virulently active where not exposed to the air. By means of forceps the overlapping conjunctiva was held away from cornea and 154 F. was applied to the ulcer for one minute with a crescentic pointed applicator.

January 25: The patient had rather marked pain last night. The ulcerative process had stopped. There was a small quantity of fresh blood within the substantia propria at the center of the cornea. This was probably due to a small central perforation, although the anterior chamber was not collapsed and the iris did not touch the cornea. This perforation confused the effects of the heat somewhat, as such ulcers often improve rapidly after corneal perforation. The hypopyon had gone.

February 6: There had been no pain since the last note. Chemosis was gone. Epithelium was growing in over the surface of the cornea. Tension was subnormal. The anterior chamber was very shallow or absent. The iris and pupil were still visible, although the cornea was now somewhat turbid, as a result of reparative processes. There had been no foci of infection since the last heat application.

The ultimate outcome is still pending. The usual course of such a severe infection as this is total loss of the cornea with expulsion of the lens, etc.

Case 4.—A laborer, aged 39, was referred to me for heat treatment by Dr. Meyer Wiener, and treatment has been conducted by us jointly. The man had been struck in the left eye three weeks before by a nail. There was a perforating wound of the cornea somewhat nasal to the center. A yellow abscess 2 mm. in diameter extended nasally from the wound toward the limbus. Earlier in the case this was an abscess with hypopyon, and the diagnosis of pneumococcus infection was established by Dr. Wiener. Under surface medication this improved until the epithelium covered the ulcer and converted it into an abscess. Improvement then ceased and extension began in the substantia propria. There was an exudate on the anterior capsule, and numerous posterior synechiae.

Jan. 29, 1917: Under thorough anesthesia with 5 per cent. cocain in suprarenal extract, 1:1,000, from 154 to 155 F. of heat was applied for one minute with a 2 mm. applicator. Continuous application was made. The patient had some pain. After the application an area 4 mm. in diameter stained with fluorescein. The center of the abscess stained more deeply than the rest of the area, which would indicate that the abscess had been unroofed.

February 2: The patient had had very little pain since the application of the heat. There was now a small moderately active ulcer at the deepest part of the former abscess. The epithelium was all replaced except over this small area.

February 5: There was an exacerbation, with more pain. The ulcerative process was active; 153 F. was applied for one minute with a 2 mm. applicator. The area about the ulcer turned slightly gray. The deepest part of the ulcer still appeared of a somewhat yellow hue. The application caused but little pain. Half an hour after application, the patient complained of the eye burning. This was quieted with an instillation of atropin and cocain oil solution.

February 8: There had been no pain since the last application. There was no discharge. There was no activity except possibly in the center of the site of the ulcer deep within the stubstantia propria.

February 10: There had been continued improvement, and no further pain. The site of the ulcer was somewhat gray. There was no staining with fluorescein. In this case it would have been better to use an applicator with a somewhat rounded, bullet pointed tip than one with a flat surface 2 mm. broad. The heat would have then been carried more effectively into the center of the ulcer. Such applicators have since been constructed.

These cases tend to confirm the experimental conclusion that heat, when properly used, is an effective therapeutic agent in pneumococcus infection of the cornea. It will be observed that the temperature is about what is stated as necessary for the immediate death of pneumococci in culture (from 65 to 70 C., 149 to 158 F.[2]). All temperature readings given in this article are those indicated by the thermometer. These readings are the ones most convenient to use in actual practice. In the previous article it was shown that the temperature of the surface in contact with the eye was less than that indicated by the thermometer, and that as the temperature increased this difference increased. When the thermometer indicates from 150 to 155 F., the temperature of the surface in contact with the cornea, while in contact with the cornea, is about 4 F. less than the thermometer shows. The temperature of 152 F., therefore, which was found sufficient for the death of pneumococci in the cornea of the rabbit's eye, was actually only about 148 F. This difference was measured by means of a junction of a thermocouple placed in a fine hole drilled through the tip of the applicator parallel to the surface in contact with the eye, and as close to it as possible.

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[2] Besson: Technique microbiologique, Ed. 4.

In all the work up to the present, the thermophor used has been the compact but rather complicated one shown at the Detroit Session.[1] It consists of a resistance coil, sensitive regulating strip, platinum contacts, etc., and was primarily designed for maintaining constant temperatures in the applicators for long periods of time. For practical purposes for one minute applications, a much simpler apparatus can be used.

The parts of such a simplified instrument are shown in Figure 1. In the upper part of this illustration are four bullet-shaped objects (*a*). These are the applicators. Each one is hollowed out so as to receive the bulb of the thermometer. Just below these is shown the "core" (*b*) with an applicator and thermometer in position. This core is a heavy piece of brass (or copper) tubing 4 inches (about 10 cm.) long and 9/16 inch (about 14 mm.) in outside diameter. One end has a lock-nut in it for holding fast the thermometer, while the other end is reamed out properly for snugly receiving the applicators. The larger object (*c*) below is a metal case 1¼ inches (about 32 mm.) in diameter, and a little over 4 inches (about 10 cm.) long. This is heavily lined with felt, has an opening at each end and a hollow space through the center just large enough to receive the core. It is an insulating jacket for retaining the heat. Figure 2, shows the jacket with core, thermometer and applicator in position as when ready for use.

When it is desired to use the instrument, a properly shaped applicator is selected and slipped into the end of the core. The thermometer is then slid through the

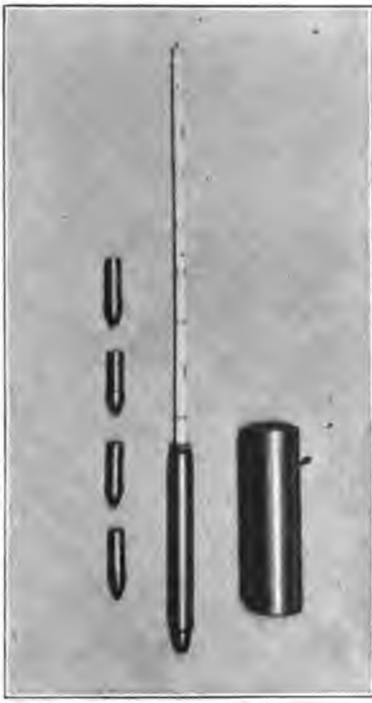

Fig. 1.

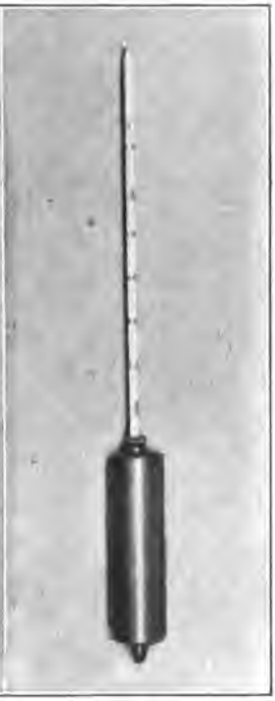

Fig. 2

Fig. 1.—Thermophor parts. (*a*) applicators; (*b*) core with applicator and thermometer in position; (*c*) felt lined insulating case.

Fig. 2.—Assembled thermophor, as it appears when ready for use.

lock-nut and core until its bulb is in the applicator as far as it will go. The thermometer is then fastened in place by a few turns of the lock-nut. Then, with the thermometer used as a stem, the core is held over a flame, as that of a Bunsen burner, until the mercury in the thermometer reaches about 170 F. The core is then slipped into the insulating jacket, where it will be held by the friction of the felt. The mercury in the thermometer is then observed until it falls to 156 F. At this instant the tip of the applicator is placed in contact with the ulcer and held there for one minute. During this time the mercury will fall from 5 to 10 F., according to the size of the tip of the applicator. The method of use is illustrated by the following case:

A coal miner, aged 50, was referred to me for heat treatment, Feb. 13, 1917, by Dr. E. C. Spitze of East St. Louis. He had been struck in the left eye ten days previously by a piece of coal. A pneumococcus infection set in and was treated by various cauterizing agents by Dr. Spitze. Also a hot copper mass was held as near the ulcer as the patient could stand for five times. Despite these measures, the ulcer steadily increased in size and severity. When he came to me, February 13, there was an ulcer 3 by 2.5 mm. in the lower nasal quadrant of the cornea nearer to the center than the limbus. There was marked injection of the bulbar conjunctiva, beginning iritis and much pain. The patient had been unable to sleep the past two nights. There was moderate discharge. The stage of hypopyon had not yet been reached. A smear revealed pneumococci.

The eye was thoroughly anesthetized with 5 per cent. cocain in suprarenal extract, 1:1,000, for about fifteen minutes. During this period the applicator, in position in the thermophor, was held against the ulcer several times before it was heated so as to accustom the patient to it. Care was taken that the word heat was not used in his hearing. When the eye was ready the core was slipped out of its jacket and heated over a Bunsen burner out of sight of the patient. The core was then slipped back into its jacket and the instrument laid on a table in view of the patient while the mercury was falling to 156 F. During this time more anesthetic was instilled and the thermophor picked up. At the proper moment the patient's lids were held apart with the fingers of one hand while the applicator in the thermophor was held against the ulcer with the other. The patient did not notice any difference between this application and the former ones made before the core and applicator were heated. Consequently he was calm and held perfectly still. The application, therefore, was constant and thorough. A casual question afterward elicited the response that it did not hurt. A 3 mm. applicator was used for this. An area 4.5 mm. in diameter was denuded of epithelium. Shortly after the application considerable pain developed and was controlled by cocain, or oil solution of atropin and cocain, about every half hour for about three hours. The pain was such as follows a burn.

February 14: The patient "slept fine" last night. There was no discharge. No pain was felt. The ulcer was clean and everywhere free from yellow infiltration. Epithelium was replacing itself from all parts of the periphery. The area of denudation was now 3.5 mm. in diameter. Atropin and cocain (1 per cent. each) oil solution was used several times. Excellent mydriasis was obtained.

February 15: There were no pain and no discharge. The ulcer was replaced by gray surface. The area of denudation was 3 mm. in diameter. It was washed with physiologic sodium chlorid solution. Atropin and cocain in oil solution were used. A light bandage is kept on all such eyes until the epithelium is completely replaced.

February 16: There was no complaint. The area of denudation was 2 mm. in diameter. Treatment was as described above.

February 17: There was no complaint. The area of denudation was 1.5 mm. in diameter.

February 19: There was no complaint. The conjunctival injection was disappearing. An area of 0.75 mm. stained with fluorescein. There was steady filling in of the excavation in the substantia propria. There was no undermining or any symptom of pneumococcic activity. With + 1.50 sph. V. $^{20}/_{60}$ +. The iritis had done no harm. The nebula was eccentric. The prognosis for complete recovery was absolutely good. Yet I have seen just such cases as this go to complete destruction of the cornea with extrusion of the lens, in my own hands as well as in the hands of my associates, despite most vigorous and conscientiously applied methods. The somewhat higher initial temperature of 156 F. was used because the temperature of 152 F. constantly maintained did not always stop the process in one application in the human cornea, and because in the simplified thermophor the temperature is steadily falling during the application.

In using the thermophor care must be taken to see that the thermometer is in order. One series of experiments was spoiled by a small volume of gas (some thermometers have a small amount of nitrogen in their stems) breaking the column of mercury and holding it so that the parts could not reunite. When this occurs the thermometer bulb is put into a freezing mixture and cooled until the mercury is all in the bulb. The gas then diffuses itself in the stem and the mercury column rises unbroken. Another series was spoiled by an appreciable quantity of the mercury becoming fixed in the small dilatation at the top of the thermometer stem. This gave false readings which caused the use of points hotter than was desired. In this case the bulb of the thermometer is cautiously heated over a flame until the mercury in the stem reaches and unites with that in the dilatation. On cooling, the mercury sinks as a continuous column and correct readings are obtained.

NOTE.—Since the foregoing article was written, nine additional cases of serpiginous (pneumococcus) ulcer have been treated by means of the simplified thermophor. The results have been most gratifying. The infective process was stopped definitely in all but one case by one or two heat applications. It was found best, however, to use an initial temperature of 158 F. instead of 156 F. as being more certain to stop the process in one application of one minute's duration. Also a series of experiments on the normal corneae of rabbit's eyes showed that one minute applications up to 170 F. merely increased the depth and intensity of the resultant nebula without causing any necrotic changes leading to corneal perforation. A temperature of 190 F. (dropping to 180 F. during the one minute application) caused intense whitening of the substantia propria, followed in a few days by extensive vascularization of the treated area and some bulging of this area but no necrotic changes leading to perforation.

The effective temperature 158 F. for one minute is, therefore, far within the limit of safety for therapeutic uses on the cornea.

I am under much obligation to fellow ophthalmologists, especially Dr. E. C. Spitze of East St. Louis for collaboration in the cases reported.

MEMORANDA

CRYSTALLINE DEPOSITS IN THE EYE*

F. PARK LEWIS, M.D.
BUFFALO

A study of life processes, even though we are not able to arrive at final conclusions, is always a subject of great interest. For the ophthalmologist a condition in which side by side with the normal functioning of an organ or a tissue may be seen a return to the elemental substances of which it is composed is peculiarly important, because in the eye alone, of all of the tissues of the body, he may follow Nature at work in her laboratory. He may see the blood vessels swelling in congested areas. He may observe the serous transudation, becoming in time a plastic exudate. If he cannot actually discover the blood vessel in the act of breaking, he can at least determine its location and disposition when a hemorrhage occurs. He is able to note the process of absorption or of disintegration of the transuded fluid, following it finally to the point at which, through retrogressive changes, it is reduced to its ultimate constituents, and glistens in the retina or scintillates in the vitreous as scattered masses of bright light reflecting crystals of cholesterin or atrophic patches of pigmentary degeneration. It is of interest to him, moreover, as he recognizes these end-results, degenerative changes which he may trace back to their origins, because having observed their termination he may the more readily perceive the earliest tendencies which, if continued, may lead to like disastrous results. It is a condition, furthermore, that appeals to him as a pathologist, as the same forces that impede the progress of normal physiologic processes in the eye during life may be producing similar changes in remote parts of the body where they cannot be seen, and where their existence may be only inferred from the presence of symptoms which are more or less misleading.

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* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June, 1917. Publication rights reserved by the American Medical Association.

I have ventured, therefore, to choose a somewhat unusual subject, for though I may be unable to add any very new facts in relation to it, it may be worth while for us to consider in what tissues of the eye a reversion to the deposit of crystalline substances may occur, how these processes are brought about, and what they connote.

CRYSTALLINE CASTS IN THE CORNEA

It has been exceedingly rare in my experience to find in an eye, otherwise functioning normally, an extensive deposit of lime salts in the cornea. That they should occur is in itself an evidence that that particular part of the cornea has lost its vitality. One special case, coming under my observation some years ago, impressed me strongly:

The patient, a man then beyond middle life, and seemingly in perfectly normal health, had been under my care some twenty years before. At that time he suffered from an extensive corneal burn, involving both eyes and leaving deep opacities. Only the upper parts remained clear, and he was able to see through these by reason of iridectomies that I had made at the time, and had been thus enabled to carry on his work as a carpenter. After so many years he came again—with the ocular conjunctiva of the better eye on which he had chiefly depended highly injected and intensely painful. The sensation was as though it were filled with sand. The condition had been growing worse for weeks until it finally grew unbearable. The surface of the cornea presented the usual white nebulous appearance of a thick leukoma, with the vessels of the conjunctiva everywhere enlarged and extending to the limbus. On touching the surface with a probe I found that it gave a hard stony or glassy impression, and by running the point of the probe over the surface I found that a solid limy deposit had settled on the surface of the cornea, and while the surface seemed smooth, the epithelial covering had been wholly rubbed away by the lid and it was actually covered with fine elevations like pin points, in reality giving the effect of an extensive foreign body. With some little effort I succeeded in prying the mass from the eyeball, and it came away in the form of a perfect cast, the inner surface especially being honeycombed where it had adapted itself to the roughened surface of the substantia propria of the cornea. The outer superficies were also roughened, giving the appearance of having at one time been smooth, but the more prominent parts seemed to have been worn off, either from the attrition of the lid or from the chemical action of the secretions of the eye. On the edges of the cornea several smaller flakes were scaled off in the same way. In some places it was necessary to take a sharp knife to scrape off the mineral deposits, so intimately had they fixed themselves in the interstices of the corneal fibers. The removal of the deposit ended the discomfort from which the patient suffered, and he has never had any recurrence so far as I know.

Similar deposits not infrequently develop in scar tissue, resulting from old corneal ulcers in which the epithelium has been destroyed. They are always slow in forming, and the pathology seems to be the same in both instances.

Occasionally lime deposits may be found in the substantia propria of the cornea in which there have been no previous inflammatory changes. These seem to be of much the same character as the structural degeneration which occurs in the elastic tissue of the vessels in arteriosclerosis.

CALCAREOUS DEGENERATION IN THE SUBSTANTIA PROPRIA CORNEAE

A spare, feeble old man, whose arteries had for many years been hard, had had for a long time nebulae scattered through the cornea. More recently these had grown dense. In the right eye a mass occupied the pupillary area and was perhaps 2 mm. in diameter, gradually thinning toward the edges. The arcus semilis had taken on such a degree of density that it could with difficulty be distinguished from the white scleral tissue. A relatively clear area formed a circular zone of sufficient breadth to show almost the entire iris and a small and not very mobile pupil. In course of time the lens became opaque, and as there existed a good projection field and blindness was already present, with no hope of improvement, I yielded to his importunities and extracted the lens. As the knife engaged the cornea the sensation conveyed to the hand was that of cutting a tissue filled with ashes, and even the sound of scraping could be heard as the blade encountered the hard limy deposit with which the tissue was strewn. This was undoubtedly a very rare condition and was allied to the "nodular opacity" in which Treacher Collins says that calcareous deposits are sometimes found.

The operation proceeded without any other unusual incident. Healing was followed by no inflammatory reaction, but so advanced were the degenerative changes that the small amount of improved vision obtained by the operation gradually disappeared.[1]

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[1] A condition closely allied to this rare form of corneal degeneration is described by Collins and Mayou as "transverse calcareous film of the cornea."

The concretions, which in the conjunctiva or on the tarsus have been considered of sufficient importance to have been carefully studied by Fuchs, are not of infrequent occurrence in the eyes of elderly people or when the eyes have been irritated or inflamed. Sometimes they are wholly encysted, occasionally they protrude through the epithelium, appearing as white or yellow bodies, and until they are removed cause much discomfort.

The concretions are the result of mucoid exudate in retention cysts. They are of the same character as the concretions found in degenerate chalazia.

Calcareous and osseous degeneration of the choroid have been so carefully studied, and so much has been written concerning these conditions, that I shall only briefly refer to them. The deposits, as were shown many years ago, are not in the choroid proper, but in the fibrous exudate between the choroid and the retina. Ossification is the last of the degenerative changes that occur in plastic choroiditis.

In eyes which have been subject to any long continued inflammatory process, calcareous concretions may be found in almost any of the tissues.

Bietti[2] found limy deposits in the optic nerve head. There was glaucomatous cupping in which new tissue was formed as a result of retinal inflammation, and in this the lime salts were deposited.

In nine cases reported by Rumschewitsch,[3] ossification and calcification were found in different structures in the eye. In six there was a deposit of bone in the choroid which was not confined to the choriocapillaris. In two there was ossification of cyclitic membranes. In one there was a bony mass inside the vascular layer of the choroid with calcareous deposit in the retina.

Albertotti reports two cases of bony mass within the choroid.

Roy[4] records a calcifying fibroma of the orbit.

Arboleda, a South American ophthalmologist, describes a condition characterized by the presence of minute calcareous bodies in the palpebral conjunctiva, frequently seen in Bogota, usually at the lid margins and at the culdesac.

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[2] Bietti: Ztschr. f. Augenh., January, 1908.
[3] Rumschewitsch: Arch. f. Ophth., 1908.
[4] Roy: Montreal Med. Jour., 1908.

All of these conditions must be distinguished from conjunctivitis petrificans, to which attention has within the last few years been directed. Sidler-Huguenin records a remarkable case of the latter condition occurring in a hysterical girl, aged 16. It was induced by her putting lime in the conjunctiva sac and grinding it into the lids, by scarifying the conjunctiva and by contusing the lids. Chemically and anatomico-pathologically it differed scarcely at all from previously described cases of this remarkable form of conjunctival disease, and the author thinks that by a careful study of the patient, this disease as an entity may disappear from our literature.

The disease is so unusual that it may bear a brief description. The best description of it available is that found in the American Encyclopedia of Ophthalmology. It was first described by Leber in 1893, and is characterized by the presence in the conjunctiva of inflammatory swelling in which opaque white spots may be seen. The spots consist of lime in organic crystallizable combination. They increase in size as the disease spreads spasmodically, and finally coalesce, forming a hard, stony mass. New foci will appear while others are healing, and the process thus lasts for months or years. These smaller foci are said to vanish by absorption, while the larger ones coalesce into shriveled, thickened spots on the conjunctiva; but those who have seen cases of this kind do not explain how it is possible for a limy concretion to be absorbed. Blindness is through corneal involvement, and the treatment consists of removing such a focus when it is possible to do so.

Del Monte, the Italian ophthalmologist, gives a detailed history of a case of this kind which came under his observation, in which the *Bacillus xerosis* was found to be present. The *Bacillus xerosis,* we know, is commonly found both in health and in disease. Indeed, it was the only micro-organism present in a large proportion of the cases of infantile ophthalmias reported to our local board of health during the past winter. There seemed to be a xerosis epidemic.

In Del Monte's case, in an eye previously sound, hyperemia of the tarsal conjunctiva and the fornices suddenly came on and remained there for about four days, accompanied by very copious secretion, and then on the middle portion of the tarsal conjunctiva below and in the inner sectors of the conjunctivae of the globe, sometimes relatively large and single, at other time minute and multiple, these being accompanied by sharp pain and profuse lacrimation. The epithelium over these hemorrhages was shed as grayish white detritus, the aspect of the parts resembling that of a burn of the membrane, the margins clean cut, but the floor irregular, covered by whitish or yellowish foci, not easily removed even with scraping, the whole aspect of the exudate tough, membraneless, smooth, not elevated, and surrounded by considerable hyperemia, as well as the resulting scars, strongly suggesting the appearance of a diphtheritic ulcer. Other little foci appeared also without being preceded by hemorrhages, similar in appearance, always small in size, and whitish. The healing of these superficial ulcerations, and then the return of pain, hemorrhages and the formation of fresh lesions went on for a time as narrated. Apart from an injection of serum no treatment seemed to produce any effect whatever.

The pathologic examination was exceedingly interesting. The process, it seemed, divided itself into two periods, as shown from the microscopic examination of portions of the tissue excised at an early stage in the morbid process. At a very early stage there was loss of epithelium, although the surface was smooth. In the substance the lymph spaces were very large, so much so that at parts the tissue was almost reduced to a large mesh network. In this tissue the vessels were dilated, with edema of the endothelium in all the coats. In the parts later removed there were signs of copious serous and cellular exudation which had parts in the interior of the fibous tissue.

Del Monte's impressions from carefully made examinations are that the first step in the morbid process was an edema and cellular inflammation. Following this, by the absorption of the fluid, and in consequence of the pressure undergone which would, of course, be accentuated by the existence of highly resistant fibers, calcification might easily take place with partial necrosis of the tissues. Micro-organisms were obtained from the surface of the ulcers and from the broken down tissue, as well as from the surrounding zone of infiltration. Occasionally under the epithelium, at the edge of the ulcers, would be found large cells such as are seen in xerosis. Two forms of organisms were frequently present, one bacillary and the other coccal, but not, the author concludes, staphylococcal. He was unable to identify it with any measure of certainty. The xerosis bacillus was found deeply penetrating the tissues, sometimes even in leukocytes and in great numbers in the epithelial cells. Successful treatment followed the use of Behring's antitoxin serum.

Few cases of this rare disease have been reported. Among the most important is that of Laeber before the Heidelberg Congress in 1895. Cases have also been observed by Reif and Mayweg and by Posey in this country.

Perhaps the most typical form of degeneration which may go through the various phases to the deposit of the lime salts is found in the lens as it develops into cataract.

When the lens begins to sclerose the fibers are drawn more closely together. With this is a contraction of the intrafibrillar cement, a narrowing of the fibers, and a firmer interlocking of their crenated edges. Between these shrunken fibers the interfibrillar fluid collects in drops. Gradually the opacity extends until the lens is ripe. Following the period of maturity comes that of hypermaturity, in which the cortex liquefies, forming an opaque milky fluid. The surface of the capsule loses its radial markings and presents a homogeneous surface on which little white specks may sometimes be seen. These are due, according to Mayou and Collins, to calcareous deposits in secondary cataracts which form as a result of the diminished intracapsular tension. Ultimately degenerative changes progress in morgagnian cataract, the fibers undergo fatty degeneration, minute droplets form in them, giving rise to a granular appearance, these run together, and the fibers break down. In this way spaces are formed in the cortex of the lens containing a mixture of albuminous globules and drops of fat. As the cataract progresses, these spaces open up into one another, and more and more fibers undergo degeneration. Ultimately the whole cortex may become liquefied, and sometimes contains cholesterin crystals.

I have given this detailed description of the retrogressive changes which take place in the reduction of the lens from a vital organ into its primitive salts because it is exactly interpreted by our knowledge of cytology. In all life processes the structure proceeds from the simple to the more complex, from the elemental to the composite. When the vital bone ceases to be dominant the complex structures revert, going back again, step by step, through the same processes to their simple constituents.

The more important advances that have been made during the past decade have been along the line of physiologic chemistry. With the upbuilding in its simplest form of the substances found in air and water into the protoplasm which becomes organized into living structures, capable of performing the functions for which it is designed, there must be corresponding retrogressive changes. In order that that perfect equipoise may be secured, the balance of the increment and the excrement of the cell must be maintained. This balance being once destroyed, the initiation of structural degeneration will have begun.

In considering this reversion in the living body to primitive forms we are looking on the last phase of organic life. It is the end-product of a long series of changes, of which the beginning was in the cell. There would be little of value, or even of interest, in recounting such conditions, even as curiosities in pathology, if they carried with them no intimation of the reason why the vital energy had departed, and why with its departure the structure, which it had held together, fell to pieces. This the study of dead tissues, no matter how carefully performed, fails to tell us.

The first altered pathologic condition which we see is macroscopic; the next is microscopic; the third — that which is most helpful — deals with physiologic chemistry.

BIOLOGY OF THE CELL

In every case of disease there must have been a wide range of gradations, from the initial disturbance of nutrition through the breaking down of structures, up to the final dissolution of the material into the elements of which it is composed. The end-results are visible to the naked eye. They are more fully detailed under the microscope, but they can be comprehended only through our study of physiologic chemistry. Permit me, therefore, in a word to recall a few of the important facts which have a bearing on the biology of the cell.

Every living cell, no matter what may be its function or ultimate destination, is a mass of protoplasm enclosed within a cell wall. It has in its substance proteins, lipoids and an enzyme. It is in fact a colloid in which crystalloid substances are readily soluble. Under the influence of chemical action, of heat, of electricity, of light or of radioactive forces, the cell is split up into the component carbohydrates, the molecules forming new groupings, through a long series, until the simpler forms are finally reached.

As Pauli has shown in his various lectures on "Physical Chemistry in Medicine," physiologic experience compels us to believe that chemical reactions of the most different kinds are simultaneously possible in the homogeneous ground substance of the cell; and in even the smallest particles of protoplasm, antagonistic chemical reactions, such as oxidation and reduction, hydration and loss of water, condensation, synthesis and their opposites, assimilation and dissimilation, are liable to occur through and beside each other.

Just as the chemist allows different chemical reactions to take place in different vessels, the cell is believed to ultilize the different chambers of the honeycomb structure, and with the help of the colloidal ferments, the number and knowledge of which is daily growing, allow the necessary reactions to go on independently of each other.

In order that we may visualize these cellular activities, which are constantly taking place, we must think in terms of cell structure continuously related. With such colloids as the cornea, the membrane of Descemet, the lens capsule, the lens cortex, the vitreous, the hyaline membrane, the nerve cells of the retina and the membrane of Bruch in contact with such colloids as the lymph and the blood plasma, with the aqueous filled with crystalloids in solution, with each cell penetrable by the toxins given off from bacteria or from chemical changes, we may begin to realize the enormous possibilities that are opened up to us, not only concerning the physiology and the pathology of the eye, but as to the therapy as well. The same laws, it will be remembered, govern the cell contents and its membrane as to osmosis and surface pressure as apply to other animal membranes, and while it is not yet proved, it is not at all improbable that the edema within the eye, whether it takes the form of an acute or a chronic, a simple or a fulminating glaucoma, may ultimately be found to be due to the swelling within the vitreous cells of soluble toxins. Equally the atrophic changes in the lens fibers, like the fibrous and subsequently fatty changes in xanthelasma, or in the arcus senilis, are evidences of the presence of soluble toxins which have disturbed the normal functioning of local cells.

Therapeutically it is clear that every drug substance introduced into the animal body must be ionized before its constituent electrons can activate those within the living cell. This is, of course, aside from the subject under consideration. It has been most interestingly treated in a little volume by Leduc entitled "Electric Ions and Their Use in Medicine."

The acute or chronic inflammation of a tissue is only an intermediate stage, and is produced by a local irritation which may be due to a toxin introduced by some pathogenic bacterium.

Practically all forms of uveitis that are not traumatic, and many that are traumatic, are due to this cause. We no longer speak of rheumatic iritis. We look for the source of infection of both the rheumatism and the iritic inflammation. It may be found in an apical tooth abscess, it may arise from an infected sinus, or it may be as remote as the appendix. From such a locally infected point the toxin given off by the bacterium, the staphylolysin or the streptocolysin, is readily absorbed by the blood plasma and carried to the uveal tissues. Many illustrations come readily to mind, but one will suffice:

A lad of 18 had for five years been suffering from choroiditis. Large patches of exudation had been followed by atrophy, involving the macula of one eye, and coming dangerously near the visual center of the other. He had been under able, conscientious and expert care. When he was seen in midsummer in consultation it was evident that there must be somewhere a nidus, a focus of infection. He was seemingly perfectly well, free from both tuberculosis and syphilis. An investigation of his nose at first revealed nothing but a swollen middle turbinal. His rhinologist was urged to remove it for exploratory purposes. When this was done, immediately a mass of thick yellow pus appeared. The ethmoid was fully explored, opened and cleaned, and the active disease in the choroid became quiet. Two months later a new attack supervened, when a deeper hidden infected cavity was disclosed, and a roentgenogram revealed a blind abscess at the root of a molar tooth. Both were relieved when some weeks later a third attack developed. On this occasion the small, hard, sunken tonsils were removed, and both were found diseased. Since then there has been no recurrence of the active uveal disease; one cannot but feel, however, that had the source of the trouble been recognized much earlier the young man might have escaped the handicap of defective sight for the remainder of his life.

One hesitates to speculate, but the facts so rapidly accumulating all seem to point to the absorption of different toxins as a possible, if not a probable, cause of both glaucoma and cataract.

In a recent case of glaucoma, in which excellent iridectomies had been made by an eminent Scotch surgeon, and in which only a remnant of sight remained, there were evidences of extensive choroiditis. The poor woman, finally in perfect health, had lost every tooth. She said that during the years in which she was steadily going blind she suffered constantly from toothache. It is well known that no sanitary precaution has been more neglected among the poorer classes, and even among the fairly well-to-do, than the care of the teeth.

One can readily understand from the cesspools that one finds in the mouths of those from whom more would be expected that these must be never ending sources of infection. I think that we will find, too, if we go outside of our special lines of work, that there is not a patient who comes to us, with commencing striae in the lens, who will not be found to have impaired metabolic functions. There will be a greater or lesser degree of intestinal indigestion, with the resultant absorption of toxic products. And if we would avoid the final degeneration changes, which so often are presented to us, we must seek for all possible sources of infection before the damage has been done.

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MEMORANDA

THE ANAPHYLACTIC BASIS OF SYMPATHETIC OPHTHALMIA

AN EXPERIMENTAL STUDY *

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The anaphylactic theory of the etiology of sympathetic ophthalmia is the most recent of the many theories brought forward in the effort to explain the true nature of the disease.

The theories offered in explanation of sympathetic ophthalmia fall into three general groups:

1. The theories which explain the disease through ciliary nerve reflexes. These theories may be dismissed without comment.

2. The theories which assume that the disease is bacterial in origin, through bacterial metastasis from the exciting to the sympathizing eye, either through the blood and lymph channels, or by actual migration of the bacteria along the optic tract. The objections to this theory are many. There is no proof of such metastasis or migration. Deutschmann's[1] assertions of having found an organism specific for the disease have not been substantiated. A selective affinity for the unknown exciting organism is assumed, which cannot be conceded, despite the work of Rosenow. Sympathetic ophthalmia resulting from noninfectious disorders of the exciting eye, such as subconjunctival scleral rupture and disintegrating intra-ocular sarcoma, has been reported. This is a type of sympathetic ophthalmia to which the bacterial theories cannot possibly be applied.

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[1] Deutschmann, F.: Zur Pathogenese der sympathischen Ophthalmie, III, Arch. f. Ophth., 1912, **81**, 35.

3. The cytotoxic and the anaphylactic theory. This group of theories has arisen to meet the foregoing objections. The cytotoxic theory, advanced by Golowin,[2] assumes that the disintegrating uvea in the exciting eye liberates a cellular poison, a cytotoxin, which is specific for uveal tissue. This cytotoxin is carried by the blood stream to the second eye, where it attacks the uvea, and causes the clinical condition of sympathetic ophthalmia. Valuable as was this hypothesis, as it opened up channels for new thought and investigation, yet the theory itself must at present be disregarded as an explanation of the disease, for, in spite of much investigation, little or no experimental proof has been brought forward in its support.

The anaphylactic theory may be regarded as the outgrowth of the great number of observations of the local anaphylactic phenomena which could be produced in the eye by experimental means. Before Elschnig stated his belief in the anaphylactic theory and presented his experimental work in its support, a great amount of work had been done on experimental ocular anaphylaxis. This experimental work has already been reported in detail.[3] For our present purposes it may be summarized by saying that the following well controlled experiments have been clearly established: (1) A prompt inflammatory ocular reaction is produced by intra-ocular or intracorneal injection of foreign protein in animals previously sensitized by similar injection of the other eye; (2) intravenous injection of foreign protein in animals previously sensitized by intra-ocular injection produces inflammatory reactions in the injected eye, and (3) the intra-ocular injection of foreign protein in animals previously sensitized by intravenous, intraperitoneal or subcutaneous injection produces similar ocular inflammation. It had thus been established that local ocular phenomena of an anaphylactic nature could be produced.

With the possible exception of the well known experiments of Wessely on keratitis anaphylactica, these experiments seemed to have but little clinical significance. Yet these observations of ocular anaphylactic phenomena seem to be responsible for the conception of the anaphylactic theory.

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[2] Golowin: Hypothese der Autozytotoxischen Entstehung von Augenkrankungen., Klin. Monatsbl. f. Augenh., 1909, **7**, 150.

[3] Woods, A. C.: Ocular Anaphylaxis, I, The Reaction to Perfusion with Specific Antigen, Arch Ophth., 1916, **45**, 557.

The anaphylactic theory of the etiology of sympathetic ophthalmia assumes that the disease is an anaphylactic uveitis, brought about thus: The injury to the uvea in the exciting eye, by trauma, intra-ocular tumor, etc., leads to a destruction or disintegration of the uveal tissue. This uveal tissue is absorbed, and acts as a foreign protein, or antigen, to the organism, and produces a hypersensitiveness of the organism, and especially of the homologous organ, the second eye. A reaction now takes place between the sensitized uvea of the second eye and the antigens circulating in the blood or lymph. This anaphylactic reaction or intoxication is manifested clinically as a sympathetic ophthalmia.

Bold as this theory appears at first glance, it readily explains many of the clinical observations and symptoms of the disease. In the first place, it explains sympathetic ophthalmia, whether the disease in the exciting eye is bacterial or otherwise. Moreover, it explains most readily the incubation period, usually from two to six weeks, elapsing between the disease in the exciting eye and the outbreak in the sympathizing eye. This is the period after sensitization in which the organism develops the greatest sensitivity.

This theory, however, could not for a moment be tolerated in the absence of experimental proof. It assumes several fundamental points, which were in general distinctly opposed to the prevalent ideas concerning the properties of native body protein. It assumes that uveal tissue, or some constituent of the uvea, could act as an antigen, or foreign protein, to the same (homologous) animal. This means that it must differ from practically all the other proteins of the body, for normal body protein cannot so act.[4]

This uveal tissue, after acting as antigen and producing a sensitization, must likewise be alone capable of producing intoxication. Were this not so, enucleation of the exciting eye (and the dangerous uvea) would be of no value, while the body contained other equally dangerous protein. To express it more technically, after sensitization from uveal tissue, intoxication must be from uveal tissue alone, and not for other body tissue. This is equivalent to assuming an organ specificity, and a lack of species specificity.[5]

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[4] This is a general rule. An exception, however, lens protein, has already been proved to exist.

The anaphylactic theory, as will be shown later, assumes many other points which need to be proved before the theory can be finally accepted. These cardinal points, however, (1) the ability of uveal tissue to act as foreign protein in the homologous animal, (2) organ specificity, and (3) lack of species specificity, are of such a fundamental and striking nature that it was necessary to establish these in order to command any consideration for the anaphylactic theory.

Elschnig fully realized this, and, in his presentation of the theory in its present form, presented experimental work to substantiate these assumed points.

HISTORICAL

Elschnig's[6] work, appearing in a series of papers, may be thus summarized: Using as his methods the intra-ocular injection of sheep erythrocytes and cholera vibrio extracts, and as his indexes the hemolytic titer and agglutination reactions of the blood serum, he established the fact that absorption from the eye could lead to immune body production. He then sought to determine three points, to give scientific support to the anaphylactic theory. These points were: 1. Does uveal tissue possess antigenic properties? If so, in the homologous animal? 2. What constituent of the uveal tract is responsible for such properties? 3. What are the antigenic properties as regards organ and species specificity? Elschnig immunized rabbits against various heterologous (foreign) uveae, and against homologous (rabbit's) uvea, and finally against so-called "chemically pure" pigment from the uveal tract of various animals. Thus he obtained hetero-immune and iso-immune uvea serum,[7] and pigment-immune serums. He then used the complement fixation reaction for the detection of immune bodies in these serums and the study of their properties. He found that heterologous uvea produced immune bodies, as would be expected. Homologous uvea, also, acted as antigen and produced immune bodies. With the serums of animals immunized to uvea, complement was fixed by any uvea antigen, irrespective of species; the immune bodies were organ specific. As regards species specificity, the serums of animals immunized to emulsion of whole uvea were species specific in their reactions. The serums of animals immunized to pigment, however, were not species specific. The reason for this apparent anomaly is evident. Emulsion of whole uvea contains two elements, (1) pigment which is not species specific, and (2) such tissue as blood, smooth muscle and connective tissue, which is species specific. Immunization with heterologous uveal emulsion gives an immunity not only to nonspecies specific pigment, but also to the other species specific elements in the uveal tract. The species specificity of uvea immune serums is due to the last elements.

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[5] Organ specificity implies that in an organism sensitized to a given organ or tissue, anaphylactic intoxication may be elicited only by reinjection of the same organ or tissue, with little regard to the species of animal from which obtained. Species specificity implies that, in animals sensitized to the ordinary protein of any given species, anaphylactic intoxication may be elicited by the reinjection of any protein from this species animal, with little regard to the organ. Lens, testicle and a few other proteins have been shown to be organ specific and not species specific.

[6] Elschnig, A.: Studien zur sympathischen Ophthalmia, I. Wirkung von Antigenen vom Augeninnern aus, Arch. f. Ophth., 1910, **75**, 459; II. Die Antigene Wirkung des Augenpigments, ibid., 1910, **76**, 509; III, ibid., **78**, 549. Elschnig, A., and Salus, R.: IV, Wirkung des Augenpigment, Arch. f. Ophth., 1911, **79**, 428.

[7] The term "hetero-immune serums" is used throughout this paper to designate the serums of animals immunized to foreign uvea or pigment. Likewise the term "iso-immune serums" designates the serums of animals immunized to their own species uvea or pigment.

Elschnig therefore concluded that uveal tissue could act as antigen in the same animal, and that the pigment was the constituent responsible for this property. The pigment was organ specific and not species specific.

The remaining work on this subject may be quickly summarized. Weichardt and Kummel,[8] using the doubtfully valuable epiphanin reaction, substantiated Elschnig's findings. Likewise, with the epiphanin reaction, and complement fixation, Kummel[9] demonstrated uveal antibodies in a percentage of the serums of patients with sympathetic ophthalmia. Wissmann[10] supported the anaphylactic theory by experimental work, and showed uvea immune bodies in the serum of two sympathetic ophthalmia patients by the precipitin reaction, but failed to substantiate Kummel's work with complement fixation, on the serums of these patients. Rados[11] substantiated Elschnig's work only partially. Fuchs and Meller[12] were unable to demonstrate uveal antibodies in the serums of patients with sympathetic ophthalmia. Von Szily,[13] after lending much valuable support to the theory, criticizes the antigenic properties of pigment.

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[8] Weichardt, W., and Kummel, R.: Studien über Organ-Spezifität des Uvaeiweisses, München. med. Wchnschr., 1911, **58**, 1714.

[9] Kummel, R.: Versuche einer Serumreaktion der sympathischen Ophthalmie, Arch. f. Ophth., 1912, **81**, 486.

[10] Wissmann, R.: Ueber Versuche mit Augen-Extracten, Arch. f. Ophth., 1911, **80**, 399.

[11] Rados, A.: Ueber das Auftreten von Komplement binden Antikorperen nach Vorbehandlung mit arteigenen Gewebezellen, nebst Bemerkungen über die anaphylaktische Entstehung der sympathischen Ophthalmie, Ztschr. f. Immunitätsforssch., 1913, **20**, orig., 305.

[12] Fuchs, A., and Meller, J.: Studien zur Frage einer anaphylaktischen Ophthalmie, Arch. f. Ophth., 1914, **88**, 280.

[13] Von Szily, A.: Anaphylaxie versuche mit seg. chemisch reinem Augenpigment (von Rind, Schwein und Kannchen) nebst pathologische anatomischen Untersuchungen, I, Klin. Monatsbl. f. Augenh., 1916, **56**, 79.

In this unsatisfactory state the anaphylactic theory remained. Elschnig asserted that he had shown that uveal tissue possessed the fundamental properties necessary to make the theory an actual possibility. These properties were: (1) the ability of uveal tissue to act as an antigen in the same species animal; (2) organ specificity, and (3) lack of species specificity, with the pigment being the constituent of the uvea responsible for these properties. The remaining work may be said to have enhanced the probability of the suggestion without detracting from it.

THE PURPOSE AND PLAN OF THIS WORK

The attractiveness of the anaphylactic theory and the importance of Elschnig's work cannot be disregarded or discounted, yet the theory, in the state it remained, could not be accepted. In a critical review of the subject, and of the experimental work on ocular anaphylaxis, several points are at once apparent. In the first place, Elschnig's work has never been repeated and substantiated in toto. Even granting that the antigenic properties of uveal tissue are established, other fundamental points remain to be proved. Although anaphylactic phenomena have been demonstrated in the eye by sensitization and intoxication, either the sensitization or the intoxicating dose, in every case, has been by ocular injection, with the resultant trauma obscuring the results. The anaphylactic theory assumes, however, that sensitization must be from general absorption, and intoxication from antigen circulating either in the vascular or lymphatic apparatus. Ocular anaphylactic phenomena have never been demonstrated by this means. It must be shown, therefore, that ocular anaphylactic phenomena can be produced by this vascular sensitization and intoxication, and that uveal tissue can exert its antigenic properties through the same mechanism. It must be shown that homologous uveal tissue absorbed from one eye can create a hypersensitiveness in the second. Finally, sympathetic ophthalmia should be reproduced experimentally by anaphylactic means.

In accordance with this conception of the problem, we have made an experimental study of the entire subject, attacking each phase separately. It is the purpose of this paper to present the work as a whole, bringing together the various points which establish a scientific basis for the anaphylactic theory of sympathetic ophthalmia.

Accordingly, the plan of this work was: 1. To repeat, and establish, if possible, Elschnig's work with complement fixation on the specific antigenic properties of uveal tissue. 2. To determine whether or not ocular anaphylactic phenomena could be elicited, after general sensitization, through antigen carried to the eyes by a vascular apparatus. 3. To determine the ability of uveal tissue to act through this mechanism, and at the same time to determine the specific constituent of uveal tissue responsible for this action, and its properties in regard to organ and species specificity. 4. To determine the ability of homologous uveal pigment free to be absorbed from one eye, to create a hypersensitiveness in the second eye. 5. To attempt the experimental reproduction of sympathetic ophthalmia by an anaphylactic means, through the use of uveal tissue as antigen.

I. THE ANTIGENIC PROPERTIES OF UVEAL TISSUE AS SHOWN BY COMPLEMENT FIXATION

This, as mentioned before, is substantially a repetition, in toto, of Elschnig's work.

Dogs were immunized by intraperitoneal injections repeated every six days, against cow's uveal emulsion, cow's uveal pigment and dog's uveal emulsion and uveal pigment.[14] In order to avoid nonspecific fixation, the serums of the dogs selected for this work were all examined in the complement fixation reaction with the various uveal emulsion and uveal pigment antigens, before immunization was begun. Eight dogs, giving completely negative reactions with all antigens in this preliminary work, were selected for immunization.

At suitable intervals after the last injection, the serums of these dogs were tested again against all the antigens. The results are shown in Tables 1, 2, 3 and 4. In order to quantitate the strength of the reaction, three different quantities of serums were used with every antigen. A + + + reaction indicates complete, or practically complete, fixation of complement with all quantities of serums; a + + reaction, similar fixation of complement in the tubes containing two largest amounts of serums, and a single + reaction indicates that such fixation was observed only in the tube containing the maximum amount of serum.

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[14] The details of technic used to prepare the uveal emulsion and uveal pigment may be found in the papers already published and to appear shortly.

The first two complement fixation reactions were done with the same antigens used in the preliminary reaction. The last reaction was done with freshly prepared antigens. All antigens were used in one-third the anticomplementary dose.

All animals showed immune serums, differing, as might be expected, in the various dogs. Dogs 16-96 and 16-98 showed the lowest immunity.

Table 1 illustrates the complement binding phenomena shown by heterologous immune serums. As would be expected, these serums gave complement binding with their specific antigens. Moreover, the uvea-immune serums gave fixation of complement with pigment antigens. Pigment-immune serums fixed complement with pigment antigens, showing here that the pigment itself is capable of acting as antigen.

Table 2 illustrates the complement binding reactions of the serums of dogs immunized to dog's uveal emulsion and dog's pigment, iso-immune serums. The iso-immune serums gave fixation of complement with their specific antigens, showing the presence of iso-immune bodies. In other words, uveal tissue possesses the power to act as a foreign protein — as antigen — in animals of the same species. This is the first, and cardinal point, to be proved in order to establish the anaphylactic theory. Furthermore, the purified pigment of the uvea possesses this power of immune body production in the homologous animal, and uvea-immune serum gives fixation of complement with pigment antigens. This substantiates Elschnig's contention that it is the pigment which is the responsible factor for the peculiar antigenic properties of uveal tissue.

Table 3 illustrates the organ specificity of the immune serums. Iso-immune serums gave positive complement binding reactions with heterologous antigens, and the heterologous immune serums gave complement binding with the iso-antigens. In other words, the immune bodies were organ specific, showing an affinity for antigens of the specific tissue, without regard to the species from which obtained. This substantiates Elschnig's second point of the organ specificity of uveal tissue. The pigment-immune serums

TABLE 1.—HETEROLOGOUS SENSITIZATION (COW'S UVEA AND PIGMENT)

Serum	Antigen	Dec. 14		Jan. 31	Feb. 14	Feb. 21 Fresh Antigens
16-89. Uvea-immune	Cow's uvea	Negative	Period of Immunization	++	++	+++
	Cow's pigment	Negative		++	+	+++
16-90. Uvea-immune	Cow's uvea	Negative		+++	+++	+++
	Cow's pigment	Negative		+	++	+++
16-91. Pigment-immune	Cow's uvea	Negative		+++	++	+++
	Cow's pigment	Negative		++	++	+++
16-92. Pigment-immune	Cow's uvea	Negative		+++	+++	+++
	Cow's pigment	Negative		+++	++	+++

TABLE 2.—HOMOLOGOUS IMMUNIZATION (DOG'S UVEA AND PIGMENT)

Serum	Antigen	Dec. 14		Feb. 6	Feb. 14	Feb. 21 Fresh Antigens
16-95. Uvea-immune	Dog's uvea	Negative	Period of Immunization	+++	++	+++
	Dog's pigment	Negative		++	++	++
16-96. Uvea-immune	Dog's uvea	Negative		++	+	+++
	Dog's pigment	Negative		+	Negative	++
16-98. Pigment-immune	Dog's uvea	Negative		+	+	++
	Dog's pigment	Negative		+	+	++
16-99. Pigment-immune	Dog's uvea	Negative		++	+	++
	Dog's pigment	Negative		+	++	++

show this property also, and it is evidently to the pigment constituent that this organ specificity of uveal tissue is due.

Table 4 illustrates the question of species specificity. With the serums of animals immunized to cow's uveal emulsion and cow's uveal pigment, it was determined whether or not fixation of complement occurred with antigens of cow's protein, other than uveal tissue. It will be seen by a study of this table that the uvea-immune serums give complete fixation of complement with antigens of cow's liver and kidney extract. The reason for this is that already stated — that these dogs were immunized with the whole uvea, which contained not only the uveal pigment, but also some blood, smooth muscle and connective tissue of the cow. The fixation of complement with the liver and kidney extracts is dependent on the immunization with the last factors.

On the other hand, the serums of dogs immunized to cow's pigment alone gave either weak or negative reactions with cow's liver and kidney. The pigment was purified as much as possible, but it probably still contained traces of the other elements of the uveal tract —the blood, smooth muscle and connective tissue. The weak reactions occasionally observed are probably due to this impurity.

However, the difference in the degree of fixation of complement between the uvea-immune and the pigment-immune serums with the same antigens is striking. It seems reasonable to conclude from this, with Elschnig, that the pigment, acting as antigen, lacks, at least in a degree, species specificity.

These observations of the complement binding reactions of uvea and pigment-immune serums corroborate Elschnig's findings. Heterologous and homologous uveal tissues have the power of acting as antigens. In the case of homologous uveal tissue, the pigment is the factor responsible for its antigenic properties.

Whole uveal emulsion is both organ specific and species specific, the species specificity probably being due to the blood, smooth muscle, and connective tissue in the emulsion. The pigment, however, is organ specific and probably not species specific, and in this respect is analogous to lens protein, and differs from other body protein.

These properties of uveal pigment — ability to act as foreign protein to animals of the same species, organ

TABLE 3.—ORGAN SPECIFICITY

Serum	Antigen	Dec. 14		Jan 1, Feb. 6	Feb. 14	Feb. 21 Fresh Antigens
16-89. Cow's uvea-immune	Dog's uvea	Negative	Period of Immunization	++	+	++
	Dog's pigment	Negative		+	+	++
16-90. Cow's uvea-immune	Dog's uvea	Negative		++	+	+
	Dog's pigment	Negative		+	Negative	+
16-91. Cow's pigment-immune	Dog's uvea	Negative		++	Negative	++
	Dog's pigment	Negative		+	Negative	++
16-92. Cow's pigment-immune	Dog's uvea	Negative		++	+	+++
	Dog's pigment	Negative		++	+	++
16-95. Dog's uvea-immune	Cow's uvea	Negative		+++	++	+++
	Cow's pigment	Negative		++	+	+++
16-96. Dog's uvea-immune	Cow's uvea	Negative		+++	++	+++
	Cow's pigment	Negative		++	+	+++
16-98. Dog's pigment-immune	Cow's uvea	Negative		+++	++	++
	Cow's pigment	Negative		+++	++	+++
16-99. Dog's pigment-immune	Cow's uvea	Negative		+++	++	++
	Cow's pigment	Negative		+++	++	++

TABLE 4.—SPECIES SPECIFICITY

Serum	Antigen		Jan. 31 and Feb. 6	Feb. 14	Feb. 21 Fresh Antigens
16-89. Cow's uvea-immune	Cow's liver	Period of Immunization	+++	+	++
	Cow's kidney		+++	++	++
16-90. Cow's uvea-immune	Cow's liver		+++	+++	+++
	Cow's kidney		+++	+++	+++
16-91. Cow's pigment-immune	Cow's liver		Negative	Negative	++
	Cow's kidney		+	Negative	+
16-92. Cow's pigment-immune	Cow's liver		+	+	Negative
	Cow's kidney		+	++	++

specificity, and lack of species specificity — are, as before emphasized, the fundamental properties which uveal tissue needs to possess to make the anaphylactic theory a possibility.

II. OCULAR ANAPHYLAXIS THROUGH GENERAL SENSITIZATION AND VASCULAR INTOXICATION; THE PERFUSION OF THE EYE

The second phase of the problem is the determination of whether or not ocular anaphylactic phenomena can be elicited in a generally sensitized animal through antigen circulating in a vascular system, as must be the case if sympathetic ophthalmia is the result of intoxication of a sensitized eye. Efforts have been made to study this problem in the past, but have been unsuccessful for the reason that little is known of the actual mechanism of anaphylaxis, and the relatively crude methods commonly employed for the production of anaphylactic shock did not produce ocular reactions. In an animal generally sensitzed and intoxicated, the stormy general reaction masks any ocular response; and the quick death or recovery of the animal makes protracted study impossible. If a smaller intoxicating dose is given, the action is evanescent, and finer anaphylactic reactions may not occur. In order to determine, therefore, whether or not anaphylactic ocular phenomena may occur in a generally sensitized animal through antigen carried to the eye by a vascular apparatus, we have resorted to the perfusion of the eye. The apparatus employed has already been described.[3] Figure 1 shows diagrammatically the operation and the position of the inflow and outflow cannulas.

With this technic we were dealing with what was to all purposes a living eye, maintained on an artificial circulation with defibrinated blood oxygenated by an artificial lung. Although the dog's heart always ceased to beat after the final ligature was placed above the heart, nevertheless the winking reflex persisted in the eyes often for an hour or more.

In this experiment the eyes were perfused for three hours, constant observations being made throughout that period.

It was found that when a sensitized dog was perfused with the defibrinated blood of a normal dog, there was no ocular reaction. When, however, the specific antigen (the antigen to which the dog was sensitized) was added to the perfusion fluid, a prompt contraction of the pupil occurred, and as the perfusion continued, small hemorrhages appeared throughout the fundus. The contraction of the pupil was marked, usually from a dilated pupil from 10 to 12 mm. in diameter to a pupil from 2 to 4 mm. in diameter. This observation is in direct accord with those of Dale and Schultz, who observed the contraction of sensitized smooth muscle in the presence of specific antigen, and is another observation in support of the cellular theory

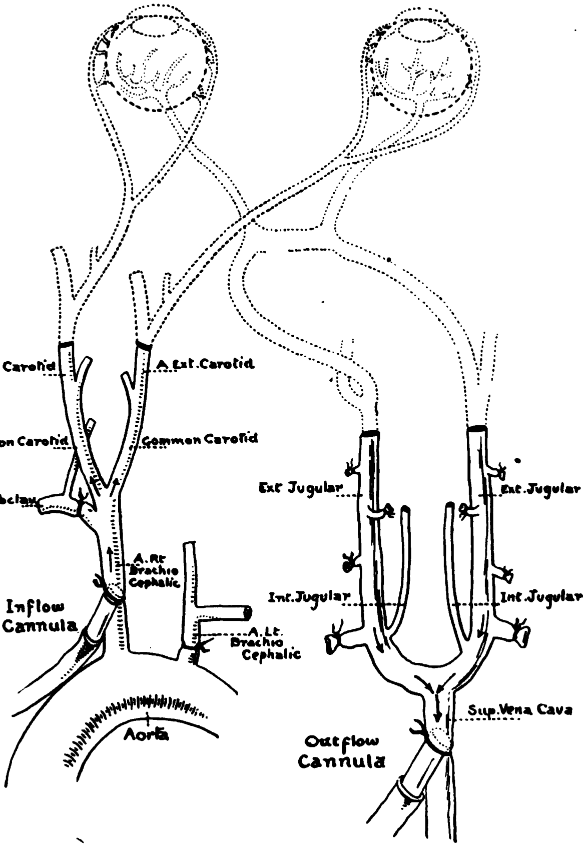

Fig. 1.—Diagram showing operatin, position of inflow and outflow cannulas and scheme of perfusion.

of anaphylaxis. The hemorrhages observed cannot be so easily explained. Petechial hemorrhages have been observed over the peritoneum of animals recovering from anaphylactic shock, and it may be that these are analogous. From their method of formation it appeared that they were caused by an alteration of the endothelium of the capillaries, allowing a diapedesis of red cells.

In this experiment, the antigens used were horse serum and cow's uveal emulsion. Before we proceeded with the second phase of the perfusion work, a number of perfusions were done to control this observation. These controls are illustrated in Table 5. One of these controls requires a little explanation. Normal dogs perfused with horse serum showed a slight contraction of the pupil, never over 3 mm. Schultz[15] has shown that fresh horse serum possesses the power to produce a slight contraction of smooth muscle, and this is evidently what occurred with us. This contraction of the pupil in normal dogs, perfused with horse serum, was never over 3 mm., while the contraction in the sensitized dogs was from 8 to 10 mm. Normal dogs perfused with uveal tissue showed no contraction of the pupil.

TABLE 5.—CONTROLS

Sensitization	Perfusion Fluid*	Result	
		Contraction of the Pupil	Hemorrhages in Fundi
None	D. B.	None	None
None	D. B. + uveal emulsion	None	None
None	D. B. + horse serum	Never over 3 mm.	None
Uveal emulsion	D. B.	None	None

* In this and the following tables, D. B. = defibrinated blood of normal dogs.

It may be concluded, therefore, that the eyes may be sensitized as a part of general sensitization, and that anaphylactic phenomena may be elicited in the eyes by means of antigen carried by the blood stream. These anaphylactic phenomena consist in a marked contraction of the pupil, and in small extravasations of blood throughout the fundus.

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[15] Schultz, W. H.: Physiological Studies in Anaphylaxis, I, The Reaction of Smooth Muscle of the Guinea-Pig Sensitized with Horse Serum, Jour. Pharmacol. and Exper. Therap., 1910, **1**, 549.

With the artificial condition under which we were working, it is manifestly impossible to expect inflammatory phenomena of any kind, but the establishment of the fact that ocular anaphylaxis, no matter how manifested, may be demonstrated by a general sensitization and vascular intoxication gives us the second important point in the establishment of a scientific basis for the anaphylactic theory. Moreover, this observation affords us a means of studying the anaphylactic properties of uveal tissue, in vivo, by direct observation of the eye.

III. THE ANTIGENIC PROPERTIES OF UVEAL TISSUE IN THE PRODUCTION OF OCULAR ANAPHYLAXIS; PERFUSION OF THE EYE

In the section on complement fixation, it was shown that uveal tissue possessed the peculiar antigenic properties necesary for the anaphylactic theory of sympathetic ophthalmia to be possible. The next question is whether or not the same peculiar properties can be utilized in the actual production of ocular anaphylactic phenomena through such a mechanism as must be used in the production of an anaphylactic sympathetic ophthalmia, namely, general sensitization and intoxication through antigen carried to the eye by a vascular apparatus.

It has already been shown that an anaphylactic reaction can be obtained through the perfusion of the eye with specific antigen. This reaction has been used to determine the antigenic properties of uveal tissue. We first sought to determine whether or not whole uveal tissue possessed the antigenic properties necessary to make an anaphylactic uveitis a possibility. This point has already been established and reported.[16] We next sought to determine the constituent of uveal tissue responsible for its peculiar antigenic properties. Earlier work[16] showed that there was much reason to believe, with Elschnig, that the pigment was the responsible factor. A pigment solution has finally been prepared which was suitable for use in perfusion. Similar experiments to those in which uveal emulsion was used as an antigen have been performed to determine if the pigment was the responsible factor. The reactions given by the pigment were in every way similar to those given by whole uvea, except as regards species specificity. Moreover, dogs sensitized to homologous uvea reacted to perfusion with pigment, establishing more conclusively the fact that the pigment is responsible for the peculiar antigenic properties shown by uveal tissue.

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[16] Woods, A. C.: Ocular Anaphylaxis, II, A Contribution to the Anaphylactic Theory of Sympathetic Ophthalmia, Arch. Ophth., 1917, 46, 8.

The results of this work, both with uveal tissue and uveal pigment, are shown in Tables 6, 7, 8 and 9. The work is presented in the following form: 1. The ability of heterologous uveal emulsion and uveal pigment to act as antigen. 2. The ability of homologous uveal emulsion and pigment to act as antigen. 3. The properties as regards organ specificity. 4. The properties as regards species specificity.

TABLE 6.—HETEROLOGOUS SENSITIZATION (COW'S UVEA AND PIGMENT)

Sensitization	Perfusion Fluid	Result	
		Contraction of the Pupil	Hemorrhages in Fundi
Cow's uveal emulsion	D. B. + cow's uveal emulsion	Marked	Marked
Cow's uveal pigment	D. B. + cow's uveal pigment	Marked	Marked

Each individual observation was confirmed by at least two perfusions, and in those experiments in which for any reason (clots, thrombosis) the nature of the reaction was not clear after two perfusions had been performed, subsequent perfusions were done until the presence or absence of the anaphylactic phenomena was established beyond question.

Table 6 represents the results obtained by sensitization and perfusion with heterologous (cow's) uveal emulsion and uveal pigment. The anaphylactic reaction was observed in all of these perfusions, establishing the power of both uveal emulsion and pigment to act as antigens.

Table 7 illustrates the fundamental fact necessary in the anaphylactic theory — the power of homologous uveal tissue to produce an ocular anaphylactic reaction in a sensitized eye when carried there through vascular channels. It shows also that it is the pigment which is responsible for this remarkable antigenic property.

Dogs sensitized to homologous uveal emulsion give an anaphylactic reaction when perfused with normal defibrinated blood to which pigment is added, and dogs sensitized to pigment give the reaction when perfused with the pigment-containing blood.

TABLE 7.—HOMOLOGOUS SENSITIZATION (DOG'S UVEA AND PIGMENT)

Sensitization	Perfusion Fluid	Result	
		Contraction of the Pupil	Hemorrhages in Fundi
Dog's uveal emulsion	D. B. + dog's uveal emulsion	Marked	Marked
Dog's uveal emulsion	D. B. + dog's pigment	Marked	Marked
Dog's uveal pigment	D. B. + dog's pigment	Marked	Marked

Table 8 illustrates the organ specific property of uveal emulsion and uveal pigment. As shown before by the complement fixation reaction, uveal tissue and pigment are organ specific. The sensitization resulting from the introduction of uveal tissue into an animal is specific for uveal tissue, without regard to the species from which the tissue is taken. Dogs sensitized to cow's uveal emulsion react to perfusion with dog's uveal emulsion, and vice versa. Similarly, dogs sensitized to cow's pigment react to perfusion with dog's pigment, and vice versa. There evidently results from sensitization with uveal tissue a strong chemical affinity for similar tissue — organ specificity.

TABLE 8.—ORGAN SPECIFICITY

Sensitization	Perfusion Fluid	Result	
		Contraction of the Pupil	Hemorrhages in Fundi
Cow's uveal emulsion	D. B. + dog's uveal emulsion	Marked	Marked
Cow's uveal pigment	D. B. + dog's pigment	Marked	Marked
Dog's uveal emulsion	D. B. + cow's uveal emulsion	Marked	Marked
Dog's uveal pigment	D. B. + cow's pigment	Marked	Marked

Table 9 shows the species specificity reaction of both uveal emulsion and pigment. The same properties are shown here as were shown by complement fixation; the uveal emulsion is species specific, while the pigment is not species specific. Dogs sensitized to cow's uveal emulsion give an anaphylactic reaction when perfused with other cow protein, for here the sensitization is not alone with the pigment, but also with the other species specific protein contained in the whole uveal emulsion. On the other hand, dogs sensitized to the pigment alone show no reaction when perfused with other cow protein.

The last perfusion illustrated in this table is largely a control perfusion. Dogs sensitized to uveal emulsion give no reaction when perfused with other dog protein. Perfusion with the other elements of the uveal tract — blood, smooth muscle and connective tissue — evokes no anaphylactic reaction.

TABLE 9.—SPECIES SPECIFICITY

Sensitization	Perfusion Fluid	Result	
		Contraction of the Pupil	Hemorrhages in Fundi
Cow's uveal emulsion	D. B. + cow's serum, liver and kidney extracts	Marked	Marked
Cow's uveal pigment	D. B. + cow's serum, liver and kidney extracts	None	None
Dog's uveal emulsion	D. B. + dog's liver and kidney extracts	None	None

To sum up the work thus far, both the complement fixation reactions of immune serums and the perfusion reactions have shown that uveal tissue possesses the power to act as antigen in animals of the same species, and that the pigment is the constituent of the uvea responsible for this property. In its antigenic action, uveal pigment is organ specific and not species specific. The sensitization resulting from the absorption of uveal pigment is specific. Other body protein can produce no anaphylactic reactions in animals so sensitized. Pigment alone may produce intoxication.

In its immunologic reactions, uveal pigment stands apart, in a biologic isolation, from other protein of the body. It is of especial interest that a somewhat similar isolation in its chemical structure has also been shown.[17]

IV. OCULAR SENSITIZATION FROM ANTIGEN ABSORBED FROM THE OTHER EYE

The next point to be demonstrated in the establishment of a scientific basis for the anaphylactic theory is the fact that uveal tissue, absorbed in one eye, can create a hypersensitiveness to uveal tissue in the second eye. To demonstrate this point we have sensitized dogs by the injection of uveal tissue, both heterologous and homologous, into the vitreous of one eye. After a suitable period had elapsed for sensitization to occur, the injected eyes were enucleated, in order to remove any factor which could give a possible intoxication. One week after this, the remaining eye was perfused with the specific antigen. In every case, the perfused eye gave an anaphylactic reaction, indicating that ocular sensitization had taken place as a result of the absorption of antigen from the fellow eye. Table 10 illustrates this experiment.

TABLE 10.—OCULAR SENSITIZATION

Sensitization	Enucleation	Perfusion Fluid	Result	
			Contraction of Pupil	Hemorrhages in Fundi
Vitreous injection left eye; cow's uveal emulsion	Left eye	D. B. + cow's uveal emulsion	Marked	Marked
Vitreous injection left eye of dog's uveal emulsion	Left eye	D. B. + dog's uveal emulsion	Marked	Marked

V. EXPERIMENTAL SYMPATHETIC OPHTHALMIA BY ANAPHYLACTIC MEANS

The last step in the problem as outlined is the experimental production of sympathetic ophthalmia by anaphylactic means. This must be done with the use of homologous uveal tissue as antigen. Sensitization must be from absorption of uveal tissue from the exciting eye, and intoxication must be from antigen carried to the eye by a vascular apparatus. This phase of the work is still in course of progress, and a final report cannot as yet be made.

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[17] Samuely, F.: Tierische Pigment und Faberstoffe, in Abderhalden, E.: Handbuch der biochemischen Arbeitsmethoden, Berlin, 1916, 2, 762.

Sensitization of the eye by means of homologous uveal tissue absorbed from the fellow eye has already been demonstrated (Table 10). In the course of this experiment, the following phenomenon was twice noted: From three weeks to one month after the intra-ocular injection of homologous uveal tissue, the uninjected eye showed photophobia, ciliary injection and a sluggish pupil. The first eye was enucleated at once, with the prompt clearing up of the inflammation in the surviving eye, which was subsequently perfused with positive results.

Following this observation, we have injected a number of dogs in the vitreous of one eye with homologous uveal pigment. The eyes so injected all showed a more or less severe iridocyclitis. From fifteen days to three weeks after the intra-ocular injection, the second (uninjected) eye of these dogs began to show a ciliary injection, a lusterless pupil, somewhat sluggish in its reaction, and a marked photophobia. This condition of sympathetic ciliary irritation continued steadily with little change.

After the signs of ciliary irritation had appeared in the second eye, two of these dogs were given intraperitoneal injections of pigment—an intoxicating dose. These dogs have not done well after receiving the intoxicating dose, but we have as yet made no studies on such dogs for the detection of general anaphylactic symptoms. One dog so injected died ten days later from pneumonia, the second dog was dull and listless, and appeared ill for two weeks, with a gradual recovery to normal. The ocular reactions in these two dogs became much more intense after the intoxicating injection had been given. The dog which subsequently died showed a particularly violent ocular reaction, appearing clinically as an intense plastic iridocyclitis which progressed up to destruction of the eyes. This reaction appeared in both eyes, the injected or the exciting eye, and the uninjected or the sympathizing eye. Although it is impossible to say that the intercurrent pneumonia may not have had a bearing on the ocular condition, this appeared to be a distinctly anaphylactic reaction, the ocular flare up beginning twenty-four hours after the intoxicating injection had been given, and progressing steadily. The histologic picture, moreover, was not that of an acute bacterial injection.

The clinical history and pathologic findings in this dog are as follows:

Dog 17-12. Normal dog.

January 17: Eyes were negative to external and ophthalmoscopic examination. Anterior chamber of the right eye was tapped and the aqueous allowed to flow out. At the same time 1 c.c. of dog's uveal pigment was injected into the vitreous.

January 22: Right eye showed a rather strong iridocyclitis, with a cloudy cornea. Tension was elevated. Left eye was entirely clear.

January 30: Right eye showed the same severe cyclitis. Left eye showed a fine pericorneal injection, a slight conjunctivitis, and a faint dimming of the upper edge of the cornea. Ophthalmoscopic examination was negative.

February 2: Right eye showed the same cyclitis, not so severe as formerly. Left eye showed a moderate pericorneal injection, and a faint dimming of the upper part of the cornea.

February 6: The eyes showed no further change.

Intraperitoneal injection of 5 c.c. of dog's uveal pigment.

February 7: The process in both eyes was of the same character, but the pericorneal injection was much more intense.

February 9: The right eye showed an opaque cornea, a violent ciliary injection, and a distinct diminution in the intra-ocular tension. The left eye showed a marked pericorneal injection, and clouding of the upper edges of the cornea. The iris was regular, but reacted sluggishly.

The dog showed a marked photophobia, lying with both eyes tight shut.

February 12: Right eye showed the same violent picture, and was very soft. *Left eye:* There was a moderate conjunctivitis, marked pericorneal injection, and a generally hazy cornea. The iris reacted slightly, and there was a slight exudate over the lower half of the iris. Ophthalmoscopic examination revealed many dark masses throughout the vitreous. The tension was distinctly below normal.

The photophobia in both eyes was marked.

February 15: Right eye showed violent ciliary injection, and a cloudy cornea. The iris could just be seen, and was covered with exudate. The fundus was not seen. The eye was mushy.

Left eye was soft and mushy. Conjunctivitis was marked. Ciliary injection was very intense. Cornea was cloudy, and there was a small ulcer over the pupillary area. The iris was covered with exudate, and was irregular and immobile The vitreous was filled with opacities.

The dog was listless, and lay with the eyes tightly closed. There was a slight nasal exudate today, and the dog appeared very ill.

February 16: The dog was dead in the cage. Necropsy revealed old petechial hemorrhages over the peritoneum, and

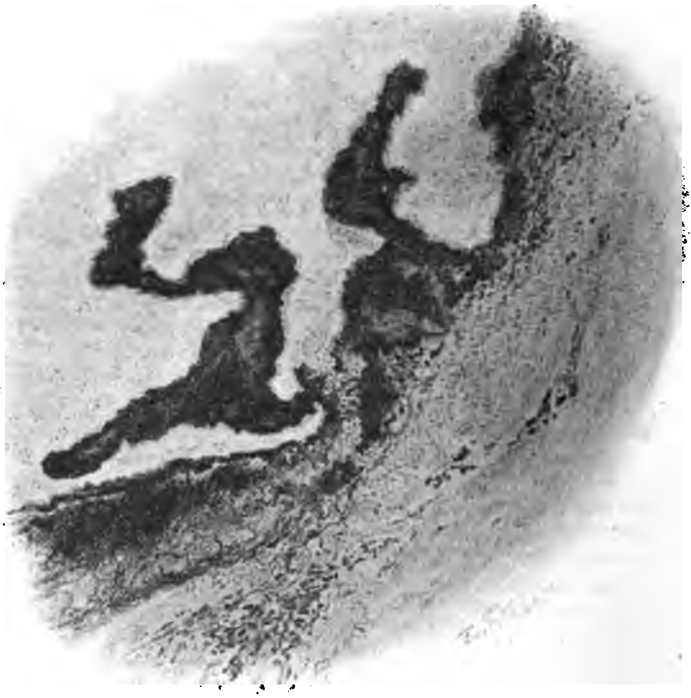

Fig. 2.—Ciliary region of eye of Dog 17-12, showing exudate around ciliary processes and round cell infiltration of choroid.

a pneumonia of the upper lobes of both lungs in the stage of gray hepatization. The necropsy otherwise was negative.

The eyes were preserved in 10 per cent. dilution of liquor formaldehydi, washed, frozen and cut.

Gross appearance.—Right Eye: The cornea was thickened, and there was an exudate in the anterior chamber. The iris was adherent to the anterior surface of the lens. Both the iris and the ciliary body appeared larger than normal. The posterior chamber was practically filled with a large exudate.

Left Eye: The cornea was thickened except over the pupillary area, where on the outer surface there was a loss of tissue. The cornea bent in at this point and was here adherent to the iris, practically obliterating the anterior chamber. The iris was adherent to the anterior surface of the lens. Both the iris and the ciliary body appeared swollen, and there was a light fluffy exudate in the ciliary region, extending up to the lens, and filling the anterior half of the posterior chamber.

Microscopic appearance.—Right Eye: The picture was obscured by the large amount of hemorrhage that had taken place. The cornea was thickened. The iris was swollen and adherent to the anterior capsule of the lens. The vitreous was filled with a mass of fibrin and red blood cells, in which the ciliary processes were embedded. There was a very small amount of pigment scattered throughout this mass. Throughout the stroma and pigment of the choroid there was a large amount of hemorrhage, and in the stroma there was an infiltration of small round cells, with a few leukocytes and epithelioid cells. The sclera was slightly thicker than normal, and showed occasional small extravasations of red blood cells.

Left Eye: There was a small eroded area on the outer surface of the cornea, over the pupillary area. In the collapsed anterior chamber there was a serous exudate in which were enmeshed many small round cells and a few leukocytes. The stroma of the ciliary body and choroid was swollen, and throughout the choroidal stroma, especially in the ciliary region, there was a dense infiltration of small round cells, with occasional epitheliod cells and leukocytes. There were also occasional small extravasations of red blood cells. The ciliary processes were embedded in a serofibrinous exudate and around them were small extravasations of red cells, with round cells and occasional leukocytes.

There was a slight migration of pigment throughout the sclera, but neither the sclera nor the retina appeared to be involved to any extent. Figure 2 illustrates the appearance of the ciliary region.

COMMENT

Although the method of sensitization assumed by the anaphylactic theory — absorption of pigment from the exciting eye — is simple, and can readily be shown, the mechanism whereby intoxication results is not so clear. It can be explained, however, by the analogy of serum sickness. Serum sickness is universally believed to be an anaphylactic phenomenon, and may occur after a single injection of foreign serum. Von Pirquet explains this phenomenon thus: In the incubation period intervening between the introduction of the foreign serum and the breaking out of serum sickness, antibodies are developed by the organism. After these antibodies have been formed, if any foreign serum (antigen) still remains in the body cells or fluids, the antibodies react with this antigen, and this interaction causes the symptoms and lesions of serum sickness. It is only a short step to apply this reasoning to sympathetic ophthalmia. After sensitization occurs through the absorption of pigment from the exciting eye, antibodies are developed by the organism, and by the second eye as a part of this general process. The interaction of these antibodies and any pigment still present in the body cells or fluids causes a disturbance, manifested in the eye as a sympathetic ophthalmia. This supposition is strengthened by the fact that we have every reason to believe that anaphylaxis is a cellular phenomenon. It is of interest, further, in this connection, that the dangerous pigment is present in the eye and nowhere else in the body. After sensitization has occurred by absorption of pigment from the exciting eye, it is readily conceivable that the antibodies in the cells of the second eye might react with the native uveal pigment, causing a localized anaphylactic phenomenon — sympathetic ophthalmia. However, the actual mechanism whereby intoxication occurs in this or in any anaphylactic condition must be hypothetic until we know more of the true nature of the anaphylactic reaction.

The ability of dog's uveal tissue to produce sensitization and intoxication in the dog has been shown. There is, however, one point further in this connection which for the present must needs be assumed. This is the ability of uveal tissue to create sensitization and intoxication in the dog from which the uvea is taken — the question of autosensitization. An anaphylactic reaction of extreme delicacy will probably be needed to show this. It is manifestly impossible to use the ocular anaphylactic reaction for this, for the eyes must be removed to obtain uveal tissue with which to work. We have attempted to show such autosensitization by removing the eye of a dog, excising and macerating the uvea, and injecting this to sensitize. Two weeks later the second eye was removed, the uvea excised and macerated, and this again injected. Under ether anesthesia this dog was observed for a fall in blood pressure, change in the coagulability of the blood, and drop in body temperature — the general signs of crude anaphylactic shock. No such signs were observed, and we have little hope of demonstrating autosensitization by this method. A more delicate method must be devised. For the present we must content ourselves with the demonstration that dog's uvea can produce ocular anaphylactic phenomena in the dog.

Fuchs[18] has asserted that the anatomic findings in sympathetic ophthalmia are characteristic. The picture is that of a round cell infiltration throughout the uvea, with occasional clumps of epithelioid cells, in which are larger cells, resembling giant cells. This observation, although not entirely confirmed by a few workers, is generally conceded to be true. There is a striking similarity between the lesions described by Fuchs as characteristic, and those shown by the dog whose history we have reported. It seems more than probable that the ocular condition in the uninjected or sympathizing eye of this animal was a true sympathetic ophthalmia. To prove conclusively, however, that an anaphylactic sympathetic ophthalmia can be produced, a greater number and more clear cut demonstrations than can now be presented are needed. Experiments in progress at present indicate that this further demonstration is a probability.

In connection with the contraction of the pupil observed in the perfusion experiments, it is of more than historical interest that oscillation of the pupil is described by Nettleship to be one of the earliest signs of sympathetic ophthalmia. The contraction of the pupil noted here, and the well known fact that sensitized smooth muscle contracts in the presence of specific antigen, is in direct accord with this observation.

The final proof of the anaphylactic nature of sympathetic ophthalmia, and indeed of the true nature of any disease, must be in man. That this will be demonstrated by serologic studies is problematic. The researches of Kummel and Wissman indicate that it is probable; but a failure by this means will not necessarily invalidate the theory, for Gay and Southard[19] have shown that, in animals sensitized to horse serum, specific antibodies cannot be shown by complement fixation.

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[18] Fuchs, E.: Ueber Ophthalmia sympathatica, Arch. f. Ophth., 1909, **70**, 465.

[19] Gay and Southard: Further Studies in Anaphylaxis, Jour. Med. Research, 1908, **18**, 407.

In this work we have endeavored to establish a scientific basis for the anaphylactic theory of sympathetic ophthalmia and to present what experimental proof we have of the anaphylactic nature of the disease. The theory assumes that uveal tissue must possess peculiar antigenic properties, and it has been shown here, and by Elschnig, that uveal tissue possesses these properties, and that the constituent of the uvea responsible is the pigment. It has also been shown here that local ocular anaphylactic phenomena can be elicited in sensitized animals by antigen carried to the eye by the blood stream, and that uveal tissue can exercise its antigenic properties through this mechanism. Uveal tissue absorbed from one eye can produce a hypersensitiveness in the second eye, and ocular anaphylactic phenomena can be produced there by uveal tissue carried by the blood stream. This is the scientific basis which can at present be advanced to support the theory.

SUMMARY

The anaphylactic theory assumes sympathetic ophthalmia to be an anaphylactic uveitis, caused by sensitization and intoxication of the sympathizing eye from disintegrating uveal tissue in the exciting eye. To fulfil the assumption of this theory, uveal tissue, or a constituent, must (1) be able to act as antigen in the homologous animal, (2) be organ specific, and (3) lack species specificity. Also (4) ocular anaphylaxis must be demonstrated in a generally sensitized animal by intoxication from antigen carried by the blood stream, and (5) uveal tissue absorbed from one eye must be capable of sensitizing the second eye.

Experimentally, these points have been demonstrated as follows: 1. By the study of the complement fixation reactions of the serums of animals immunized to foreign and homologous uvea and uveal pigment, it has been shown that uveal tissue may act as antigen in the same species animal and that the pigment is the constituent responsible. In its immunologic reactions, pigment is organ specific and not species specific. 2. The eyes of a generally sensitized animal, when perfused with normal defibrinated blood containing specific antigen, show local ocular anaphylactic phenomena. 3. Uveal tissue exercises its antigenic properties through this pathway. The pigment is the constituent responsible, and its antigenic properties are again demonstrated by this means. 4. Uveal pigment absorbed from one eye produces a hypersensitiveness of the second eye, and a subsequent perfusion produces ocular anaphylactic phenomena.

These facts constitute the present scientific basis for the anaphylactic theory.

5. Experimentally, by anaphylactic means with homologous uveal tissue as antigen, sympathetic irritation, and in one case sympathetic ophthalmia, has been produced in dogs.

MEMORANDA

OXYCEPHALUS

REPORT OF THREE CASES WITH OPERATION IN ONE *

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That oxycephaly has existed for ages is undoubted; that the ocular changes are among the most prominent symptoms is common knowledge; but that a cranial decompression may relieve the intracranial pressure, preserve vision and enable the patient to be a self-supporting member of society is too little recognized. It is to review the symptoms of three cases and to stimulate interest in this subject on the part of ophthalmologists that this communication is presented.

MacKenzie[1] in 1854 seems to have been the first to attract attention to cranial deformity as a cause of blindness. Friedenwald,[2] Fletcher,[3] Enslin,[4] Patry[5] and Hanotte[6] have recorded their experiences in communications of great value. Within the past few months, Sharpe[7] has presented a paper clearly describing his cases and recording the results of four operations. His paper should be read for the reason that only one other worker has published the report of an operation, Eiselsberg of Vienna, although Cushing has performed several operations and will soon make his

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* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June, 1917. Publication rights reserved by the American Medical Association.

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report. A similar proceeding has been suggested by several. but their cases were not so treated. I am able to find the records of only seven operations, including the one here reported for the first time.

Symptoms may pass unnoticed, but usually the headache is so severe that it attracts attention, whereupon it is found that the head is deformed and vision failing. The three symptoms of this disease are such as usually to bring these cases to the ophthalmologist primarily: (1) exophthalmos; (2) impairment of vision, and (3) cranial deformity.

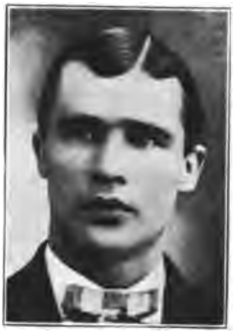

Fig. 1.—Father: Normal head; no divergence.

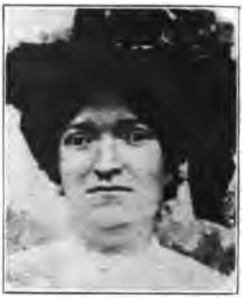

Fig. 1.—Mother: marked divergence; gross facial expression.

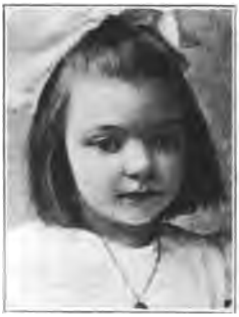

Fig. 3 (Case 1).—Patient at age of 3.

1. The exophthalmos is probably the result of the shallow orbits, and is usually accompanied by divergent strabismus and nystagmus.

2. The poor vision results from secondary optic atrophy following increased cranial pressure.

3. The cranial deformity is mainly shown by the high forehead and shallow orbits. Roentgenograms show sulcine impressions and bulging anterior fontanel.

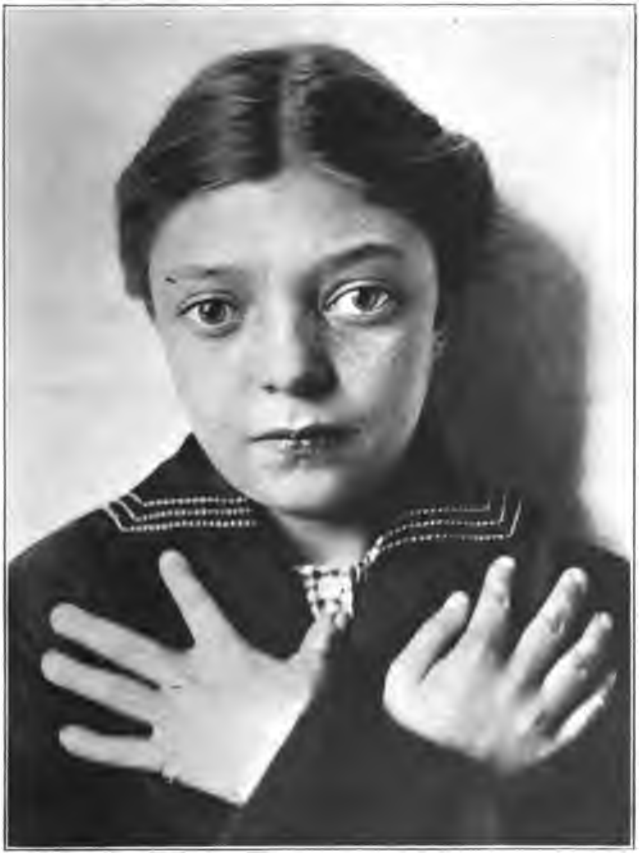

Fig. 4 (Case 1).—Full face view of patient, showing normal fingers.

Many other malformations, including webbed fingers and cardiac murmurs, have been noted.

My experience is unique. Three members of one family were afflicted; the youngest one showed optic atrophy, the middle one optic neuritis, and the oldest was free from optic nerve lesion.

The father of these children died at the age of 38, after having been in an insane asylum for two years. Necropsy proved that he had general paresis. The Wassermann reaction of his spinal fluid was positive. From Figure 1 it is seen that his head was without marked change.

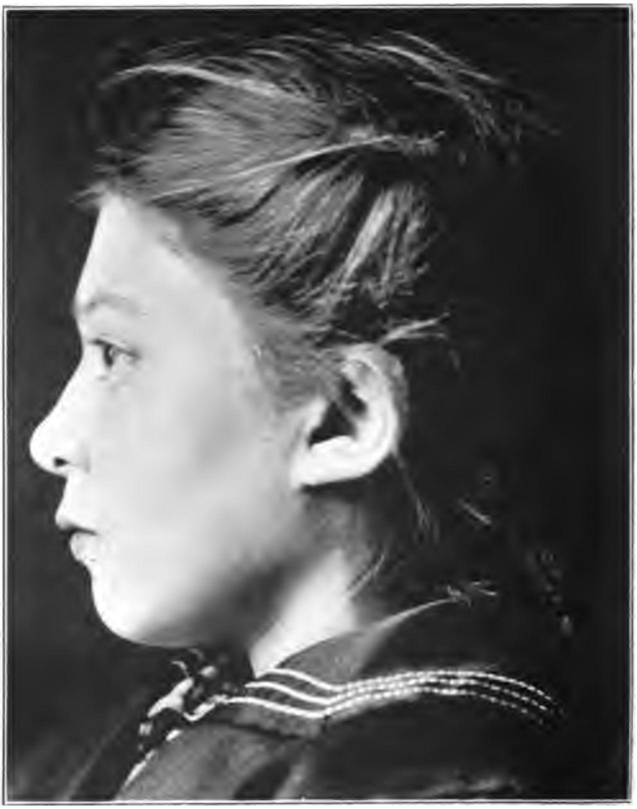

Fig. 5 (Case 1).—Profile of patient.

The mother died at the age of 30, probably from acute alcoholism. She was said to have had scars on her corneae, and Figure 2 shows that she had marked divergent strabismus with facial expression suggesting acromegaly.

The paternal grandmother died at the age of 49, from cancer of the uterus, and the paternal grandfather at the age of 78. One uncle and four aunts are living and well. The paternal great-grandparents died of old age, but it is especially noted that their heads tended to be small and the eyes closely set.

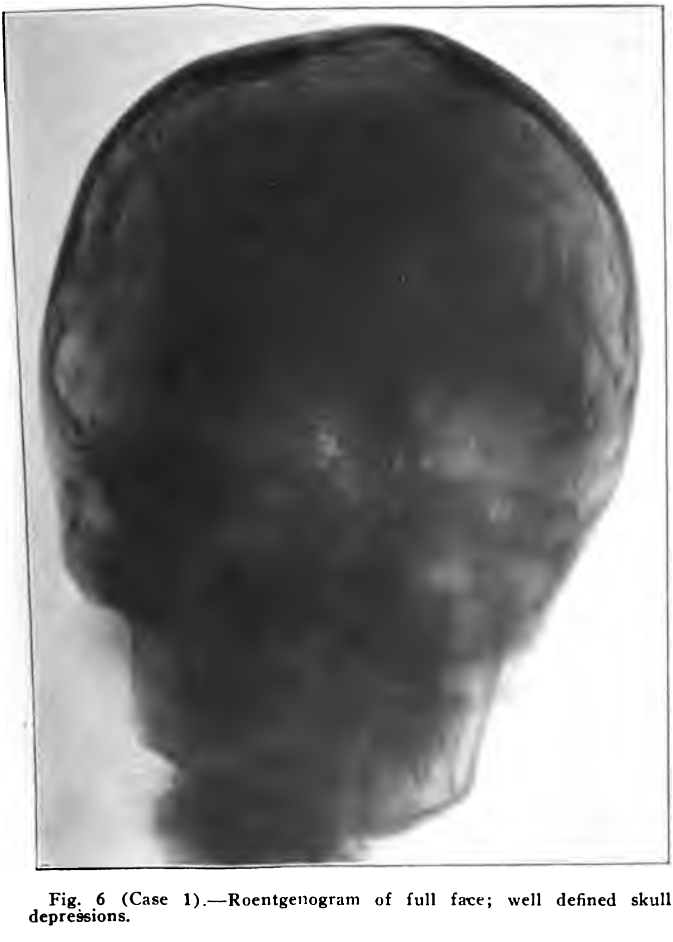

Fig. 6 (Case 1).—Roentgenogram of full face; well defined skull depressions.

The maternal history was unobtainable.

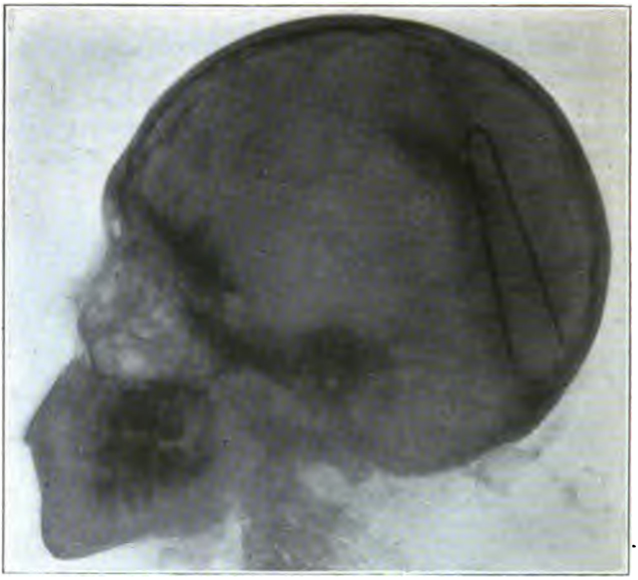

Fig. 7 (Case 1).—Roentgenogram of profile, showing depressions; deep sella turcica.

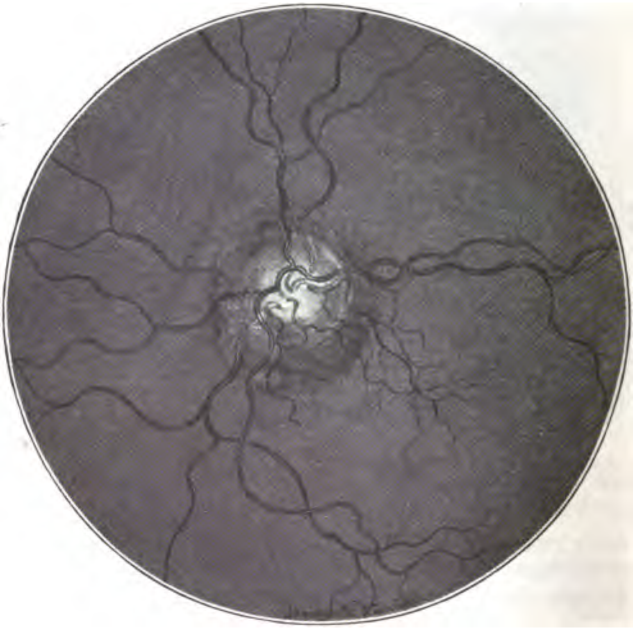

Fig. 8 (Case 1).—Practically normal fundus; slight indistinctness of the nasal margin of the nerve with slight increased vascularization.

The patients now recorded were all brought on the same day, Oct. 17, 1916.

Case 1.—A well nourished, intelligent girl, aged 11 years, with a clear skin excepting a few freckles, had normal mucous membranes; the tongue was clean, and protruded mesially with a slight tremor. The teeth, of which there were twenty-five, were well kept, eleven in the upper and fourteen in the lower jaw. There was a high palatal arch; the tonsils were not enlarged; the patient had chronic pharyngitis. The shoulders were high, the right more so than the left; the chest was comparatively short, and the patient was round shouldered. The supraclavicular and infraclavicular fossae were not depressed. The chest was flattened anteroposteriorly over the upper part. The circumference at the sixth rib was 59 cm., on forced expiration 57 cm., and on forced inspiration 62 cm. Right side 31 cm., left side 30 cm., anteroposterior diameter 17 cm., lateral diameter 22 cm. There was free and equal movement on both sides. There was slight scoliosis in the upper dorsal region.

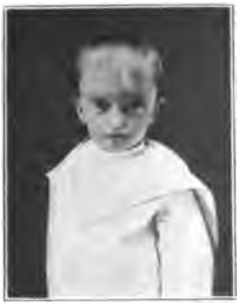

Fig. 9 (Case 2).—Patient when 2 years old: prominent frontal region.

The heart was normal in position. The apex beat was in the fifth interspace within the nipple line. Palpation revealed nothing abnormal. There were no abnormal pulsations or thrill; pulmonary resonance over the right side was normal; over the left side of the chest below the fourth rib, resonance was slightly impaired. The respiratory murmur over both sides was normal; there were no rub and no râles. The spleen and the liver were not palpable. The abdomen was 56 cm. in circumference, and not prominent. There were no herniae. Examination of the nervous and osseous systems revealed nothing abnormal excepting that the left elbow joint resisted full extension, and when forcibly extended deflected outward with the inner condyle especially prominent.

The head was somewhat square shaped, with a definite ridge over the bregma; the forehead was low. The patient had abundant brown hair. There were dilated superficial veins over the left frontal and temporal region. The circumference was 48.5 cm. From the root of the nose to the occipital protuberance, the distance was 30 cm. Biaural, 33 cm. The transverse diameter was 16.5 cm.

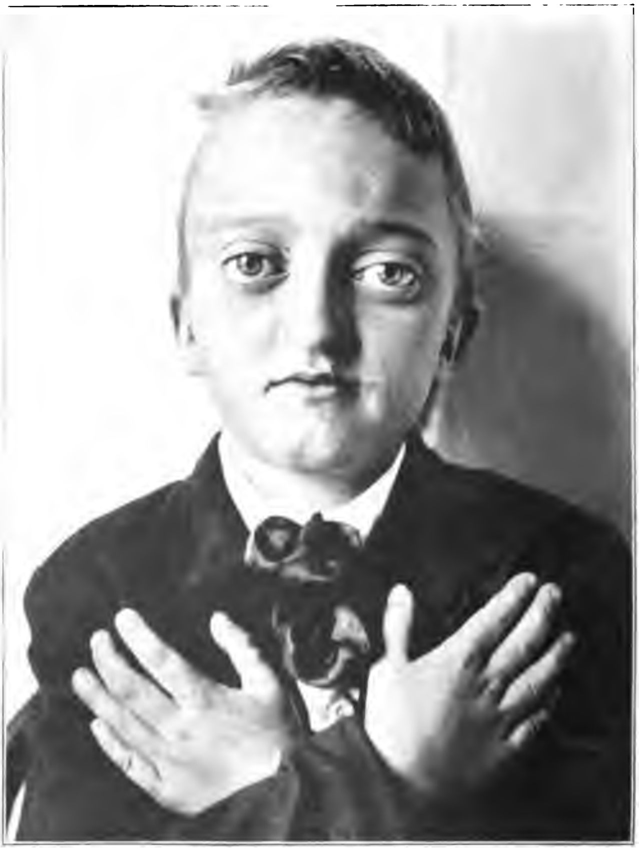

Fig. 10 (Case 2).—Full face view of patient: high forehead; tendency of left eye outward.

Right eye: vision 20/30 with + 1.25 = + .75 ax 90 = 20/20. The pupil, about 4.5 mm., was irregularly quadrate, presenting no adhesions; it was active to light and accommodation; the media were clear; the disk, with a suggestion of yellowish tinge about its margin and a small shallow central excavation, was distinctly outlined. Several small vessels passed from the temporal side of the nerve, at which part pigmentation was greatest. There were no pathologic changes, exudate or hemorrhage.

Left eye: vision 20/30 = + 1.25 = + 1.00 ax 105 = 20/20-1? The same irregularly quadrate 4.5 mm. pupil, promptly reacting to light and accommodation, and the same fundus detail were observed. There were 8 degrees of exophoria. With the Hertel exophthalmometer, both eyes 16.5 degrees.

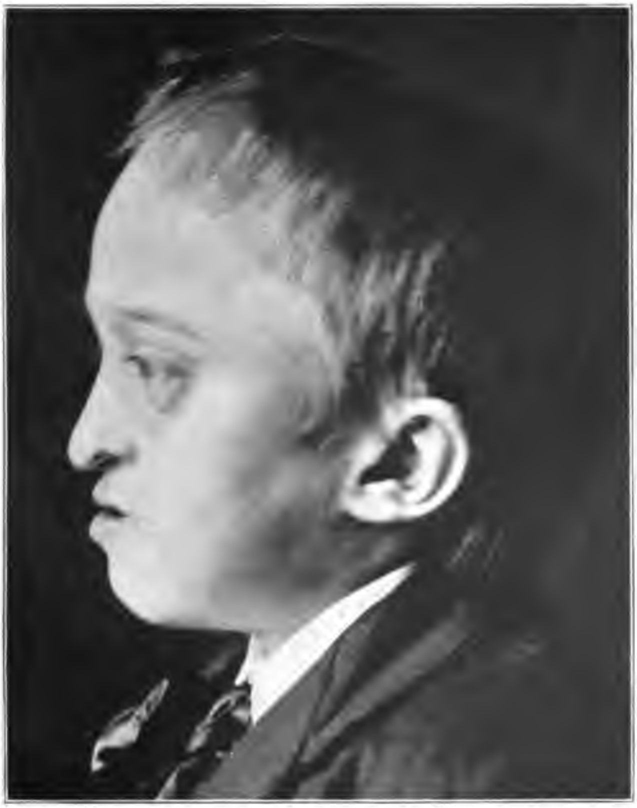

Fig. 11 (Case 2).—Profile of patient: bulging frontal region.

The only illness this patient had had was a mild attack of diphtheria when 9 years old. Figure 3 shows her condition when 3 years old. Her birth was said to have been easy, not instrumental.

Case 2.—Boy, aged 8 years, born without difficulty, not instrumental, had never had any illness. His head was of odd shape practically from the time of his birth. The earliest photograph, taken when 2 years old, revealed a peculiar face and the suggestion of frontal swelling.

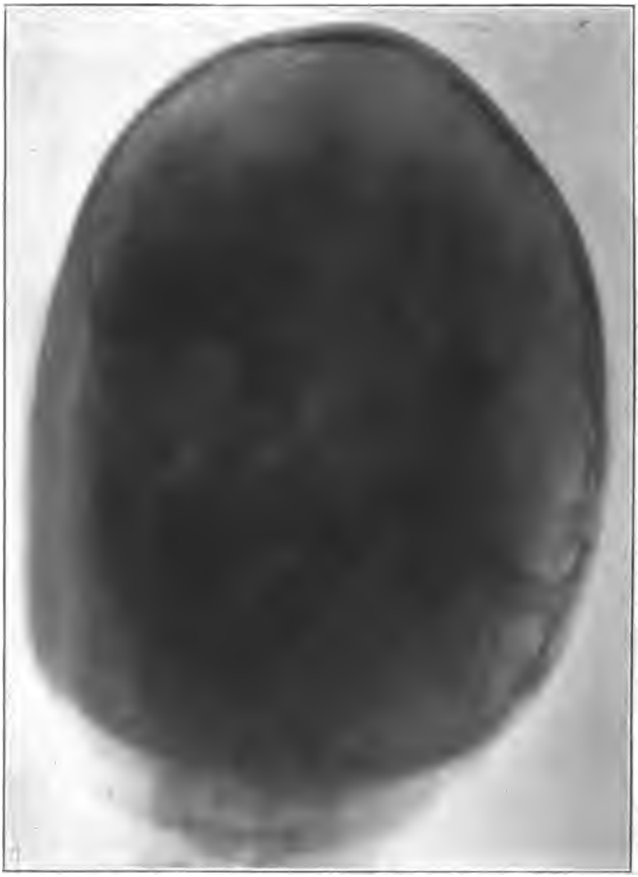

Fig. 12 (Case 2).—Roentgenogram of full face, revealing depressions on skull.

He was 114 cm. in height, with a dull, distant, vacant, stupid expression, and he was a decidedly noisy mouth breather. The skin and mucous membranes were normal. His nose was of the Roman type. The palate was decidedly arched and very high. The nasal septum deviated to the right; the turbinates were large. The ears were negative. The teeth were good, though irregular, fairly clean and not decayed, ten in the upper and twelve in the lower jaw. The lower jaw protruded, with prominent lower canines. The superficial veins of the neck were prominent. The posterior cervical glands were palpable. The chest was long, narrow and rather thin, with supraclavicular and infraclavicular fossae not remarkable; the interspaces were narrow, and the angle of the ribs more marked than normal. The epigastric angle was very acute. Breathing was of the abdominal type. The chest movement was good, and equal on both sides; there were no abnormal pulsations. The shoulders were rounded, the scapulae prominent and the spine straight. Palpation confirmed all signs of inspection. There was no evidence of early rachitis. The spleen and the liver were not palpable. There was normal pulmonary resonance on percussion. The heart outline was normal. The apex beat was in the fifth intercostal space one-half inch to the left of the nipple. Respiratory and heart sounds were normal; there were no murmurs. There were no herniae; the testicles had descended; the prepuce was adherent. The osseous system was apparently normal. Examination of the nervous system revealed nothing abnormal. The urine was negative. Blood examination revealed: hemoglobin, 95 per cent.; red cells, 4,900,000; white

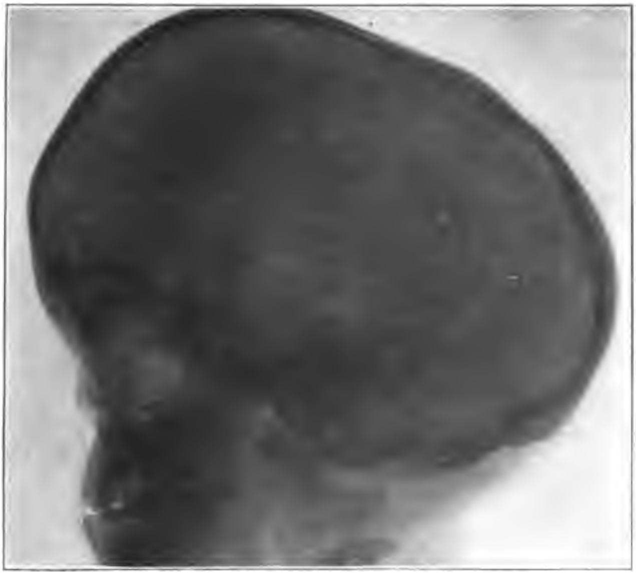

Fig. 13 (Case 2).—Roentgenogram of profile, revealing deep sella turcica.

cells, 6,300. The forehead was high, sloping upward to the vertex, with a bony ridge at the bregma. The circumference measured 51 cm. From the root of the nose to the occipital protuberance the distance was 34.5 cm.; from the root of the nose to the bregma, 15 cm.; bitemporal, 28 cm.; antero-posterior diameter, 21.5 cm.; from bregma to tip of mastoid, 17.5 cm.; transverse diameter, 16 cm. There was an abundant growth of dark brown hair.

Right eye: vision $^{20}/_{70}$. The pupil, 3.5 mm., was not perfectly round because of a straight nasal margin; it reacted to light and accommodation; the media were clear, the disk irregularly round with whitish nerve head, vessels overfull, in parts blurred because of the swelling of the nerve, which was + 3.00 D. There were no areas of hemorrhage, exudate or pigmentation.

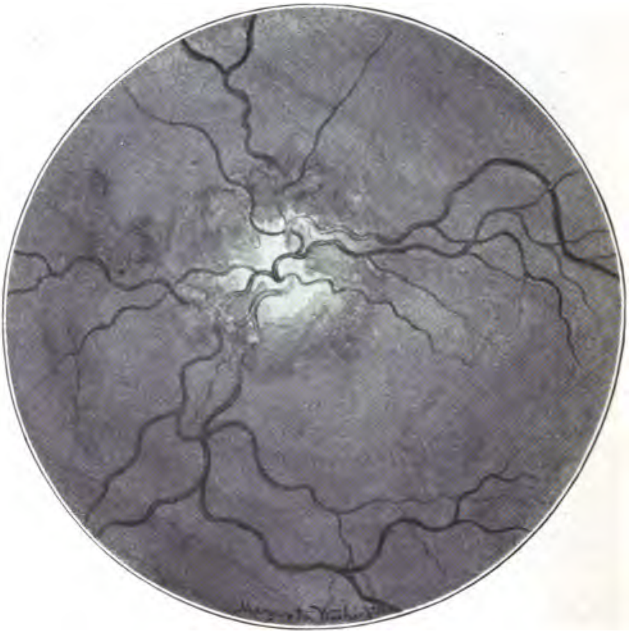

Fig. 14 (Case 2).—Fundus: blurred indistinct outline of the disk with partial obscuration of the inferior temporal vein; swelling = to 3 D.; papillitis.

Left eye: vision $^{20}/_{30}$. The pupil was irregularly oval, 4.5 by 5 mm., with straight nasal side, and reacted to light and accommodation. The same whitish swelling of the nerve head was present, with obstruction of veins and blurred outline of disk swelling = + 3.00 D.

Retinoscopic findings for each eye + 1.50. There was marked bilateral exophthalmos, by the Hertel instrument 20 degrees; nystagmus and tendency to divergence were present.

Dec. 20, 1916, the patient was operated on. A large subtemporal decompression was made on the right side. There was considerable intracranial pressure, with annoying dural hemorrhage. The patient died in a few hours. On necropsy the following was found:

The skull was irregularly elongated, measuring 21.5 cm. anteroposteriorly and 16 cm. transversely. The frontal region was unusually prominent. The inner surface of the calvarium and base of the skull showed unusually well marked depressions separated by sharp ridges. The bones of the skull were thicker than normal, measuring in the temporoparietal region 0.3 cm. in thickness and from 0.4 to 0.8 cm. in the frontal and occipital regions. The petrous portions of the temporal bones were negative. The middle ears and ear drums also were negative.

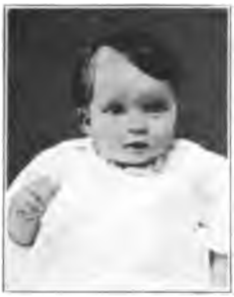

Fig. 15 (Case 3).—Patient at age of about 10 months; normal shaped head.

The brain weighed 1,380 gm. The general volume of the brain was rather considerable. It was elongated, but the two hemispheres were of equal length. The convexity appeared flattened. The left hemisphere was apparently smaller than the right. The base presented nothing unusual. There was very definite atrophy of both optic nerves.

Case 3.—Girl, aged 7 years, well built and nourished, expression not intelligent, was delivered with forceps. The skin and mucous membranes were normal. The hair was light brown and abundant. The patient was a mouth breather. There were twenty-two teeth, which were clean and decayed. The palatal arch was high, with the nasal septum deviated to the left. The tonsils were not enlarged or cryptic; there was moderate pharyngitis with adenoids. The posterior cervical glands on the right side were enlarged and palpable. The chest measured 56.5 cm.; on thorough physical examination, nothing abnormal was found in it. There was no sign of present or past rachitis. The circumference of the abdomen was 55 cm. Nothing abnormal was noted. Examination of the nervous system revealed the deep reflexes sluggish, the superficial reflexes active. The urine was negative. Blood examination revealed: hemoglobin, 95 per cent.; red cells, 5,280,000; white cells, 6,000. The forehead was high, sloping upward in conical form to a point at the bregma. The superficial veins were prominent in the frontal region. At the bregma, there was a distinct bony ridge. The circumference of the head measured 48 cm. From the root of the nose to the

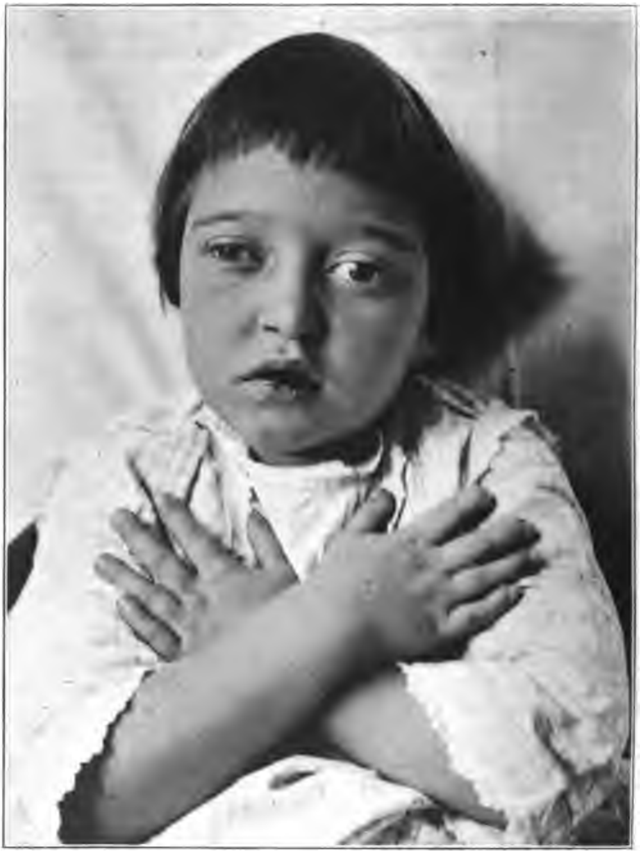

Fig. 16 (Case 3).—Full face view of patient: tower skull; extreme divergence; rapid nystagmus.

bregma the distance was 12.5 cm.; anteroposterior diameter, 20 cm.; from the bregma to the tip of the mastoid, 17 cm.; transverse diameter, 15.5 cm.

Right eye: pupil, 5 mm., slightly irregular, reacted to light and accommodation; the media were clear, the disk irregular in outline with marked pigmentation, decidedly pale, bluish white; the blood vessels were of irregular caliber. Hertel exophthalmometer, 10 degrees.

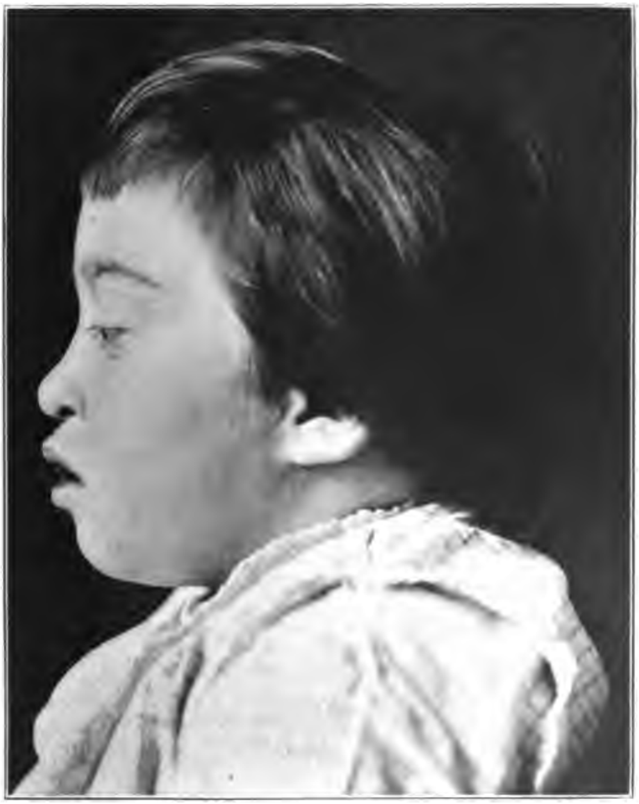

Fig. 17 (Case 3).—Profile of patient: adenoid expression.

Left eye: pupil 5 mm. slightly irregular, reacted to light and accommodation; the media were clear; the disk irregular in outline with marked pigmentation, decidedly pale, bluish white; the blood vessels were of irregular caliber. Hertel exophthalmometer, 8.5 degrees.

Retinoscope + 1.25 in each eye. There was divergence of 30 degrees with short excursive rapid lateral nystagmus. It was impossible to test the vision although she was able to get around unassisted.

The patient had never had any illness, and it was positively known that the head was without change when the patient was 2 years old. It was impossible, however, to state when alterations began.

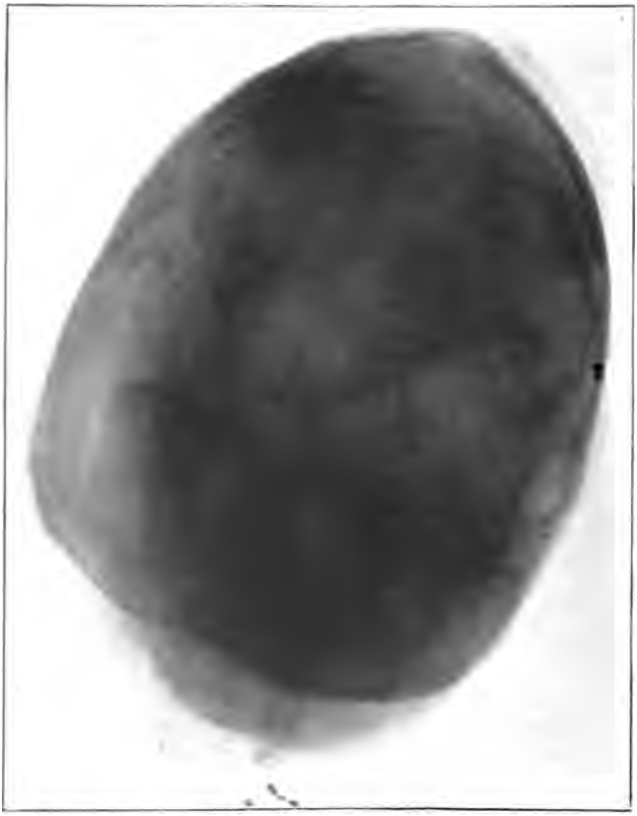

Fig. 18 (Case 3).—Roentgenogram of full face: skull depressions, apex in anterior fontanel region.

In all of these cases, the Wassermann reaction was negative.

Fletcher divides oxycephaly into three classes: those in whom cranial deformity is present at birth, those in whom the head is normal up to 2 years of age, and finally those in whom the change takes place between the second and third year of life. This classification, although to a certain extent arbitrary, offers a suggestion as to etiologic factors. Many writers consider rachitis a necessary preexistent element; but more numerous are the reporters who do not consider it an agent. Whether the syndrome be the result of meningitis, of too early closure of the fontanel, of connective tissue or even bony compression of the optic foramina is as yet undetermined. Our cases which came to necropsy showed no closure of the optic foramina, no thickening of the meninges and no sign of rachitis.

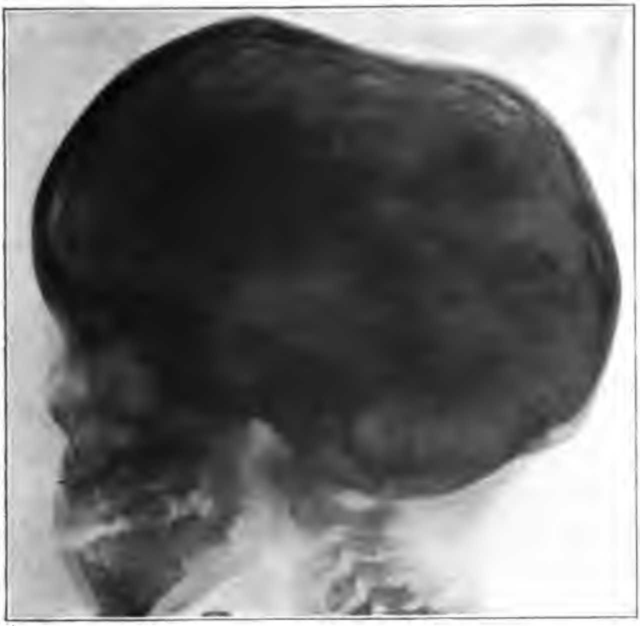

Fig. 19 (Case 3).—Roentgenogram of profile: very large sella; distinct ridge forward.

In the cases here reported, it would seem that the disease in Case 2 probably was present at birth; the only apparent fact militating against this is that although the boy was 8 years old, both optic nerves were swollen, whereas Case 3 presented optic atrophy far advanced, although it is known that the child's head was normal until she was past 2 years of age. This is a point of considerable interest in the etiologic study of the condition; for if the head in Case 2 was deformed from the beginning and the patient was only in the nerve swelling stage and the head in Case 3 did not change until after the patient was 2 years of age and she was in the optic atrophy stage, we should be forced to look for a cause in something other than just the head deformity. Furthermore, at the time of necropsy in Case 2, there was no narrowing of the optic foramina, nor were there changes about the nerve or in the dura.

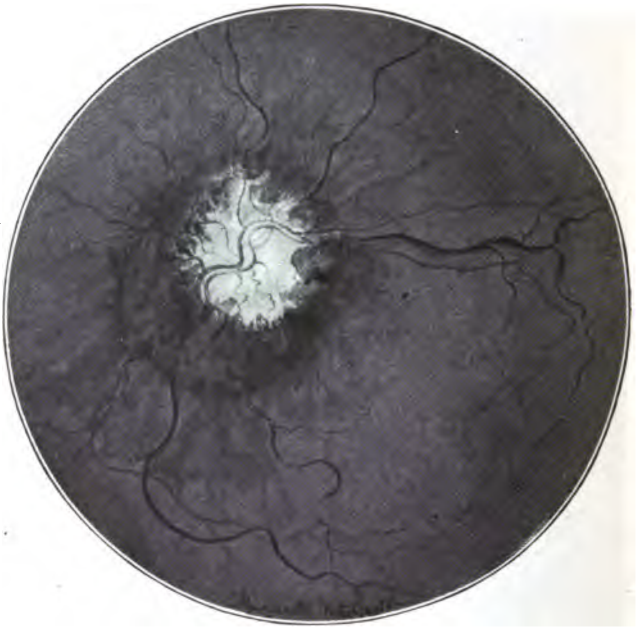

Fig. 20 (Case 3).—Fundus: disk decidedly pale, with marked obscuration and irregularity of its border, with considerable surrounding pigmentation; both arteries and veins more prominent than normal; postpapillitic atrophy.

Oxycephaly should be considered a condition easy of diagnosis and amenable to surgical relief.

I am indebted to Dr. Frederic C. Conway for the general physical examinations, to Dr. Joseph A. Cox for operating in Case 2, and to Dr. Ellis Kellert for performing the necropsy.

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MEMORANDA

MEMORANDA

THE ENDONASAL OPERATION ON THE LACRIMAL SAC*

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To many it may seem a presumption for a rhinologist to enter the sacred domain of this section and discuss a subject so intimately the field of the ophthalmologist. The *Grenzgebiet* is still a cause for strife between surgeons as between nations. My own hope is that in the domain of medicine, at least, it may soon be transcended by that higher aim, "the ultimate good to the patient," just as in national life it may ultimately be a question of "the greatest good to the greatest number." Then will humanity and benevolence rather than selfishness be the guiding principle in men's lives.

The demands of modern medicine become each day more extensive and exacting, and the specialties each day more circumscribed in their limitations. Whereas, in this country at least, it is but a short cry back to the times when the same individual encompassed, or attempted to encompass, within his domain, the diseases of the eye, ear, nose and throat; such a condition exists as a rule today only in the relatively smaller communities. Ophthalmology has come into its own as a distinct specialty, just as otology bids fair to do in the not too remote future. This assumption of authority and finality in our own limited field makes us in a way more than ever dependent on help from our fellows, according to the extent to which that field affects or is affected by the field of our fellow worker. So the ophthalmologist, who calls in the rhinologist to perform an endonasal operation on the lacrimal sac, is no more of an anomaly than the internist who invites the technician of his field, the surgeon, to perform an operation for appendicitis; the surgeon who invites the otologist to perform an operation on the mastoid process; or the rhinologist who calls to his aid the dentist in his care of a diseased antrum, or to complete the result of his tonsil and adenoid operation by attending to the proper alignment of the child's teeth. Here is an instance in which team work and not selfishness, but mutual cooperation, spells success for both, and assures, or helps to assure, a successful outcome for the patient. My own cases are only those which have been referred to me by the ophthalmologists. In fact, I have no opportunity of seeing such cases in any other way.

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* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June, 1917. Publication rights reserved by the American Medical Association.

Until a few years ago, according to West,[1] the treatment of dacryostenosis had made no real progress for a period of twenty-five years. In 1910 West published his paper entitled "The Window Resection of the Nasolacrimal Duct," and exhibited in all seven patients operated on by this method. This paper, as the title indicates, referred only to the operation on the duct, but laid no claim to being an endonasal operation on the sac. In three of the cases, however, the sac itself was really opened. West soon became convinced that the opening of the nasal duct alone could not be sufficient, and that any operation, to be successful, must concern itself rather with the opening of the lacrimal sac as well. He immediately set himself about the new task, and, through the generosity of Professor Silex of Berlin, gained access to an exceedingly rich clinical material. The results of his later endeavors he reported in 1913. At that time, he reported the investigation of over 300 cases of various diseases of the lacrimal apparatus, and the operation on the lacrimal sac in 130 cases by the endonasal method. He claimed a favorable result in over 90 per cent. of the patients so operated on.

West asserts that Caldwell was the first to open the lacrimal canal, in 1893, when he reported one case. Still later, Killian and Passow reported similar cases. The idea of reestablishing the connection between eye and nose, as a passageway for the tears, was known to the ancients, who were for the most part unsuccessful in their attempts. In 1863, Berlin had revived the extirpation of the sac from without, and this had remained the operation of choice almost to the present. In 1904, Toti published the results of his attempts to reestablish the natural pathway from without by means of a skin incision at the inner angle of the eye. In 1910, von Eiken published a paper in which the approach to the sac by way of the antrum was advocated. West performed his first operation in 1908.

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[1] West: Berl. klin. Wchnschr., 1914, **51**, 1633; Arch. f. Laryngol. u. Rhinol., 1913, **27**, 224, 504; Berl. klin. Wchnschr., 1913, **50**, 926.

The various operations, previously described, were successful only in a relatively small proportion of cases. The external operations often gave rise to fistulas, and, if successful, as far as the curing of phlegmon was concerned, necessitated later the excision of the lacrimal gland to get rid of the epiphora. The resulting scar, too, was often unsightly. West's earlier operations on the nasal duct were also unsuccessful, because the stenosis occurred at the inferior border of the sac, where it joins the duct. The operation was, accordingly, inferior to and outside the field of the real difficulty in a large proportion of cases.

West's modified operation concerns itself with the lacrimal sac alone, the duct being disregarded. The free opening of the sac itself he regards as essential, if a cure is to be expected. That the sac is really opened in all cases is shown by the fact that a probe introduced into the lower punctum passes horizontally into the nose. A minute knowledge of the anatomy of the parts is absolutely essential. The technic is as follows: A quadrangular flap, covering the end of the lacrimal sac, and extending well forward over the ascending process of the superior maxilla, is resected submucously, its base of attachment being inferior. After its resection it is turned downward out of the field of operation, this inferior attachment acting as a hinge. The denuded area extends vertically through a space roughly limited by an anterior extension of two lines, the upper marking the attachment, and the lower the inferior border of the middle turbinal. Neither turbinal is encroached on, unless an obstructing hypertrophy is present. By means of appropriate chisels, a portion of the posterior border of the nasal process of the superior maxilla is chipped away, and the thin bone, covering the sac, resected. The sac itself is then grasped with forceps and a large portion of its nasal aspect resected with a thin scalpel. The submucous flap is now replaced, the posterior part, over the area of the resected sac, being first removed. The flap is held in position for twenty-four hours by packing of iodoform gauze. The after-treatment is exceedingly simple, and consists in keeping the nose free of crusts and granulations, and irrigating the sac by way of the canaliculus with a 3 per cent. solution of boric acid. As stated before, West claims favorable results in 90 per cent. of his cases.

The advantages of West's, over the previous methods, for the treatment of the various diseases of the lacrimal apparatus, he enumerates thus:

"1. The physiologic function of the path for the tears is again restored, so that not only a suppuration of the sac, a lacrimal fistula or a phlegmon is healed, but also the tears flow normally through the nose. A later epiphora is accordingly avoided.

"2. A so-called cure by probing is rendered unnecessary.

"3. The lacrimal gland is spared.

"4. A skin incision or a curetting from without, with eventual scar formation, is avoided."

This operation he has performed in every possible sort of disease affecting the lacrimal apparatus.

After the operation, certain persons, by sharply blowing the nose, can force air out through the canaliculus. West does not consider this a disadvantage, as the patients do not complain of it. Halle's suggestion for forming a valve of the mucosa, in order to prevent this, he regards as impossible of accomplishment.

A more recent endonasal operation on the lacrimal sac is that of Yankauer.[2] The latter considers the West operation unsatisfactory because of the tendency of the opening of the middle meatus to close, such objection being avoided by his improved operation.

In the operation of Yankauer, the horizontal incision is begun at the attachment of the anterior end of the middle turbinal and carried forward for a distance of 5 mm. It is then carried downward to the anterior border of the inferior turbinal and backward along its inferior, free border, for about 2 cm., or from one-third to one-half the length of the turbinal. The incision is carried well down to the bone and the roughly rectangular flap, thus outlined, resected submucously, its posterior attachment acting as a hinge. On this hinge it is folded backward and held in place by tucking it under the anterior free end of the middle turbinal. A part of this submucous resection consists of the mucous membrane and periosteum on both sides of the anterior end of the inferior turbinal to a point well back of the opening of the nasal duct. The bony portion of the inferior turbinal, so uncovered, is then resected with punch forceps. The bony covering of the canal and sac is now removed with chisel and punch forceps, and the canal at its extreme posterior aspect slit from the opening in the inferior meatus to a point well above the junction of the inferior portion of the sac with the duct. When the sac is found to contain pus, a portion of its inner wall is resected to allow for free drainage into the middle meatus. This opening into the middle meatus closes subsequently. The internal wall of the duct and sac are now folded forward and held in position by folding the previous submucous flap down on it. The latter flap is held in position by a single stitch as well as by packing. The subsequent treatment consists in removing the packing after twenty-four hours, and irrigations through the lower punctum, the nose, of course, being kept free of crusts while healing is taking place.

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[2] Yankauer: Laryngoscope, 1912, p. 1331, Vol. XXII, Tr. Am. Laryngol., Rhinol. and Otol. Soc., 1913, 294.

Yankauer reports in all nine patients operated on by this method, during a period of three years: "Two were cases of mucocele of the sac; the other seven were suppurative. The suppuration ceased in all cases after the operation and has not recurred in any of them. The epiphora was relieved in all but one of the cases."

The most recent operation devised is that of Mosher.[3] This method of opening the sac and duct was come on, as it were, by accident from an observation of the specimens on the cadaver in the development of Mosher's operation on the ethmoid labyrinth and frontal sinus. After removal of the anterior end of the middle turbinal and free exposure of the processus uncinatus, Mosher's stiff probe is introduced through the duct into the inferior meatus, the canaliculus having previously been slit. A roughly rectangular flap, limited anteriorly by the posterior lip of the ascending process of the superior maxilla and a portion of the superior border of the inferior turbinal, superiorly by the extreme limit of the middle meatus, and posteriorly by the extreme inner tip of the uncinate process, is now resected submucously and deflected downward and backward.

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[3] Mosher: Laryngoscope, November, 1915, p. 739.

The inner wall of the lacrimal cell and bony covering of the duct are now broken through with an appropriate curet, the nasal process of the superior maxilla acting as a guide anteriorly. The fragments are removed with a conchotone. The inner wall of the duct and sac are now broken through by slowly withdrawing the probe, at the same time turning its tip sharply inward toward the septum. The probe is then reintroduced, and serves as a guide to the curetting away of the posterior tip of the ascending process of the maxilla, as well as the upper part of the processus uncinatus. The canal is subsequently widened by biting forceps after the probe is withdrawn, practically to double its previous width. A ligature is then passed through the nose upward and out through the dilated punctum, a piece of gauze being attached, kite-tail fashion, to its middle. This gauze is then drawn upward into the lacrimal sac, and the ends of the ligature fastened to the face with adhesive tape. The flap is now replaced.

After-treatment consists in removing the plug after two or three days, keeping the nose free from granulations and crusts, and keeping the passage free by passing the probe wherever it is indicated. Mosher asserts that the probe can be passed either from the nose or from the inner canthus. The operation "has been abundantly tried on the cadaver and three times on the living." Mosher admits that "it is too soon to say much about the results on the living, except that, so far, they are good."

From a review of the foregoing methods and operations it would seem that in the development and perfection of the endonasal method a possible solution of a difficulty, which has long been a perplexing one, may be reasonably expected. Certainly the external operation and its after-results have left much to be desired. The endonasal route obviates many of the disadvantages of the external operation. Whether or not the physiologic pathway for the tears into the nose can be maintained permanently in a sufficient percentage of cases at the hands of the average rhinologist is a question which time alone can answer.

The results in my own series of eight cases have been fairly good. The West operation was that of choice in all but one. In this the Yankauer operation was done. In only one case was there a complete failure. In this case the antrum was accidentally entered. Whether or not this had anything to do with the unsuccessful outcome it is impossible to say. In three cases a secondary operation was performed, that is, the stenosed opening at the beginning of the middle meatus was enlarged. All were cases of dacryostenosis and cystitis, except one. This was a case of stenosis and epiphora following a permanent opening into the antrum for empyema.

My own technic differs slightly from that of West. After the submucous flap has been outlined and elevated, a probe is inserted into the canaliculus, sac and duct. If this is difficult, the assistance of the ophthalmologist is summoned. This probe is held in place by an assistant. Its pressure renders the uncovering of the duct and sac easier. When the duct is freely uncovered, the point of the probe is directed inward toward the septum, thus bulging in its septal wall. A thin scalpel is now inserted between the probe and the lateral nasal wall, and the incision carried well up beyond the isthmus, so that the probe ultimately passes horizontally into the nose, as suggested by West. In this way a considerable portion of the duct and sac is completely removed. The infiltration of a few drops of 0.25 to 0.5 per cent. novocain solution, to the dram of which from 1 to 2 drops of epinephrin have been added, following the preliminary cocainization renders the operation bloodless, as well as absolutely painless. The only pain complained of in any of my cases was that from the pressure of the lacrimal probe.

To many this operation from its description may seem difficult or impossible of accomplishment. It *is* difficult, and this difficulty I shall not attempt to minimize. The difficulty, however, is no greater than that attendant on the submucous resection of the nasal septum, and I can assert with firm conviction that any one who can perform a submucous resection can successfully perform the endonasal operation on the lacrimal sac.

In my hands the difficulties have been considerably lessened by the use of the modification of West's instruments, which I herewith present.[4]

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[4] In addition to the references already given, the following will be found of interest:

Onodi: Monatschr. f. Ohrenh. u. Laryngo-Rhinol., **46**, No. 4.

Mithoefer: Ohio State Med. Jour., September, 1916.

Jos. B. Horgan: The Operation of Dachryocystorhinostomy: Its Indications and After-Treatment, Jour. Laryng., Rhinol. and Otol., London, June, 1916, 225.

MEMORANDA

NEUROLOGIC PERIMETRY AND A METHOD OF IMITATING DAYLIGHT WITH ELECTRIC ILLUMINATION *

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In a previous paper[1] I have described much of the technic of modern perimetry in connection with the study of color interlacing in neurologic cases, from the surgical clinic of Prof. Harvey Cushing. It was stated there that I believed it possible to imitate the daylight illumination of the perimeter and perhaps improve it in many respects by use of an arc of electric lights properly controlled and arranged. Accordingly I wish to submit in this paper an apparatus for the satisfactory perimetric examination day or night of difficult neurologic patients.

THE PERIMETRIC PROBLEM IN A NEUROLOGIC CLINIC

Probably the greatest difficulty to contend with in this group is the matter of comfort. If the patient can be kept comfortable throughout the examination, half the battle in taking a complete field at one sitting may be considered won. This is true not only because the time is greatly shortened, since the patient can make a greater number of observations without rest, but also because the answers are more accurate and consistent, thereby greatly reducing the number of readings that have to be discarded.

After the physical capacity of about 1,500 neurologic patients had been observed, it was noted that practically all of them could be moved into a reclining

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* The sequel to this paper will appear in the Trans. of the Am. Ophth. Soc. for 1917 under the title of "Quantitative Perimetry; Practical Devices."

* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June, 1917. Publication rights reserved by the American Medical Association.

[1] Walker, C. B.: Tr. Am. Ophth. Soc., 1916, **14**, 684.

wheel chair and kept comfortable for a period of two hours or so. In the worst cases the patients could at least be moved so that the head would be at the foot of the bed, slightly elevated with a pillow or two (Fig. 1). In these cases, however, perimetry is apt to be prevented by the mental state of the patient, except in the postoperative group, in which a field may be desired the first day or two after operation. In the latter group the presence of a cast or head dressing may interfere, though almost always it may be trimmed away sufficiently about the eyes (Fig. 2).

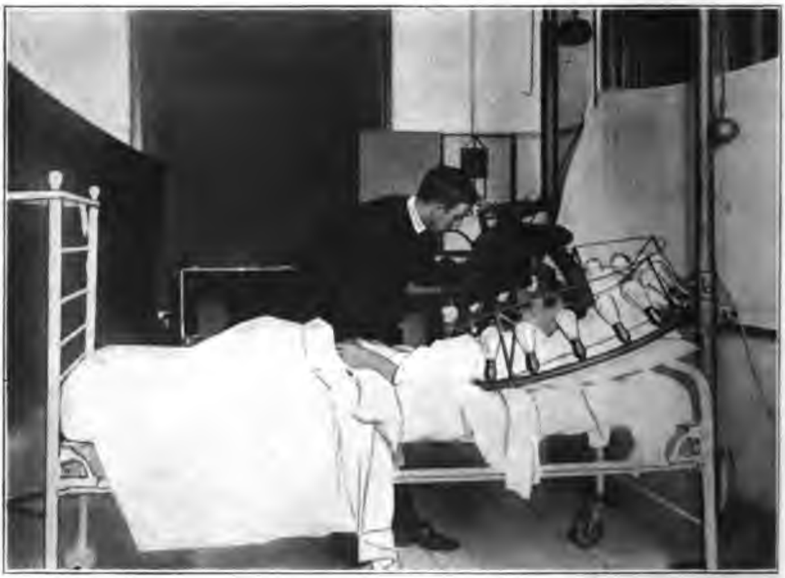

Fig. 1.—Adjustment of suspension perimeter for patient in bed.

Having determined what positions of comfort must be used, we may desire an apparatus for holding the perimeter in the proper corresponding positions; but still other conditions should be fulfilled. In the first place it is desirable to be able to take a field at any time of day or night, not only because there may be an urgent demand for an immediate report, but also because there may be only certain intervals at odd times when the patient is mentally lucid enough to be examined. Again, because of dark cloudy days, and short winter days, artificial illumination becomes necessary to meet the time requirement. But when the patient is placed in the recumbent position, even good daylight becomes unsatisfactory because most of the distribution comes from above, whereas it should come from below. Artificial illumination must therefore be used, not only because it is available at any time, but

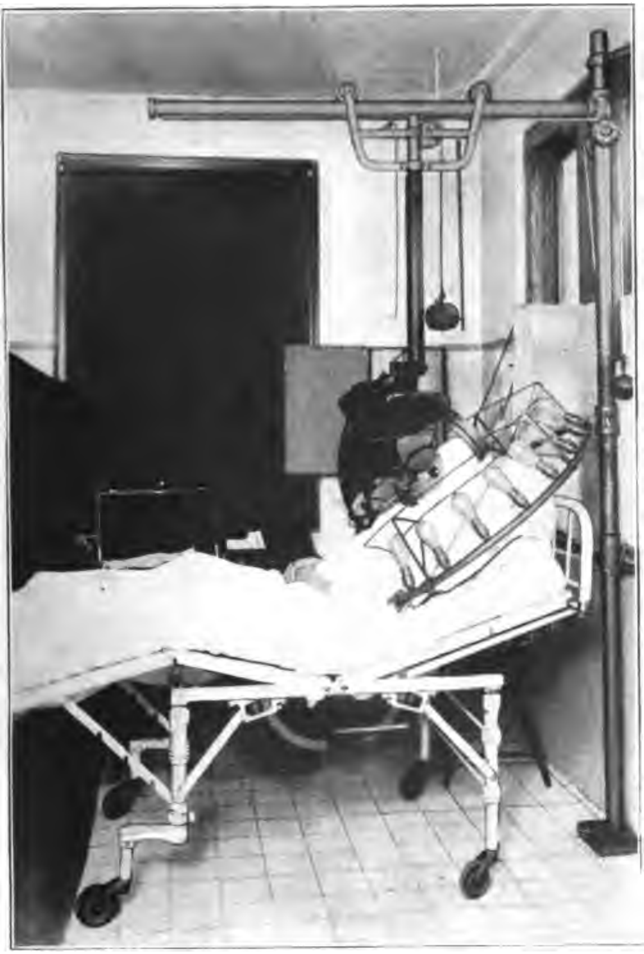

Fig. 2.—Adjustment of suspension perimeter for patient in Way bed.

also because it can be adjusted to project in any direction.

Thus we find that the solution of our problem requires the fulfilment of two conditions; first, an apparatus to hold the perimeter in proper relation to the eyes of the patient while in a comfortable reclining or sitting position, and, second, an adjustable illuminating apparatus.

THE SUSPENSION APPARATUS

It was decided that the conditions cited with reference to the proper support of the perimeter could best be fulfilled by suspension from above. Accordingly the apparatus shown in Figure 3 was designed. A glance at this shows the moving parts all supported by a right angle crane of 2 inch iron pipe held in a vertical position by a clamp to the window casing above, and below by a pivot on the floor. The projecting arm of the crane can swing through 180 degrees by this arrangement, so that the apparatus can be pushed slightly to one side or clear over against the wall, when not in use.

The perimeter is suspended from a carriage which is underslung from two rollers (*a, a*) traveling along the upper surface of the projecting arm of the crane. The carriage and the perimeter are connected by two telescoping pipes (*b*) which can be clamped together. This telescoping tube provides movement along and rotation about the vertical axis of the perimeter. At the lower end of the outside telescope pipe is a ratchet joint (*c*) to which the perimeter is clamped below. By means of this joint the perimeter can be tilted through an angle of 90 degrees from the vertical corresponding to the angle at which the patient reclines (Figs. 1, 2, 3 and 4).

In order that the horizontal motion of the carriage on the crane and the vertical motion of the telescoping pipes can be smoothly controlled, counter weights are used thus: Two cords inside the telescoping pipe are attached to the lower segment just above the ratchet joint. These cords, emerging at the top of the upper segment, pass over a pulley (*d*) which projects into the pipe through a slot. One of the cords then passes directly downward again to attach to the larger counter weight (*e*), while the other passes along the horizontal arm of the crane and over another pulley (*f*) on the upright pipe, and thence down to the smaller counter weight (*g*). The sum of these weights is equal to the combined weight of the perimeter and the lower segment of the telescoping tube. By this arrangement the smaller weight (6 pounds) not only acts as a counter weight for the perimeter but also pulls the

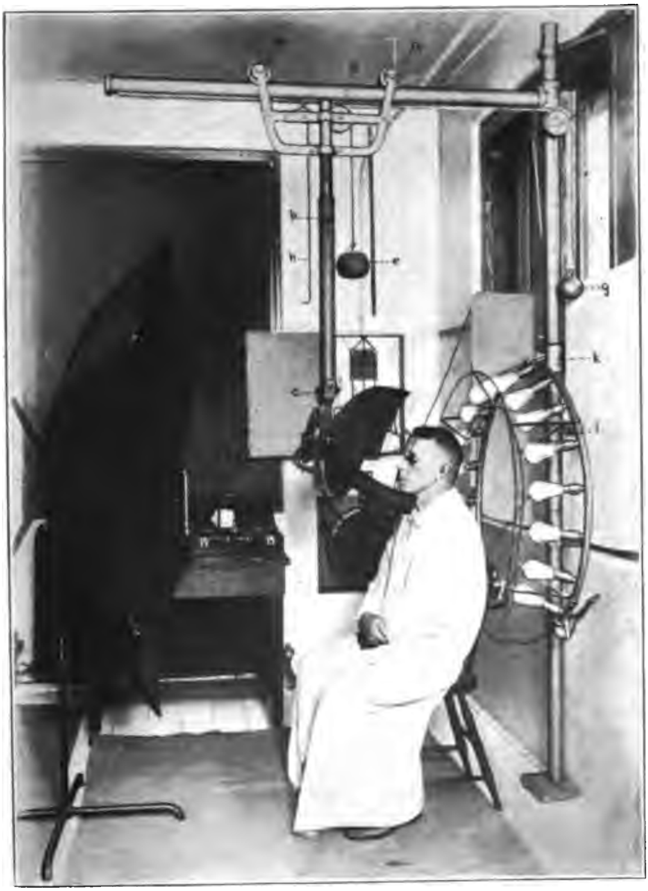

Fig. 3.—Adjustment of suspension perimeter for patient in sitting position: *a, a,* suspension carriage rollers; *b,* telescoping pipes and clamp; *c,* ratchet joint; *d, f, m,* counterweight pulleys; *e, g,* counterweights; *h,* trigger controlling horizontal motion of carriage; *k, l,* sliding sleeves for light carriage adjustment.

carriage slowly along the crane toward the patient, if the trigger (*h*) is depressed. This motion can be checked at any point by releasing the trigger (*h*), which allows a dog to escape in the notched strip of channel iron fastened to the under surface of the crane. The strip of channel iron also serves to prevent lateral swinging of the telescoping tube, the latter being grooved at its upper end to receive the projecting margins of the channel iron.

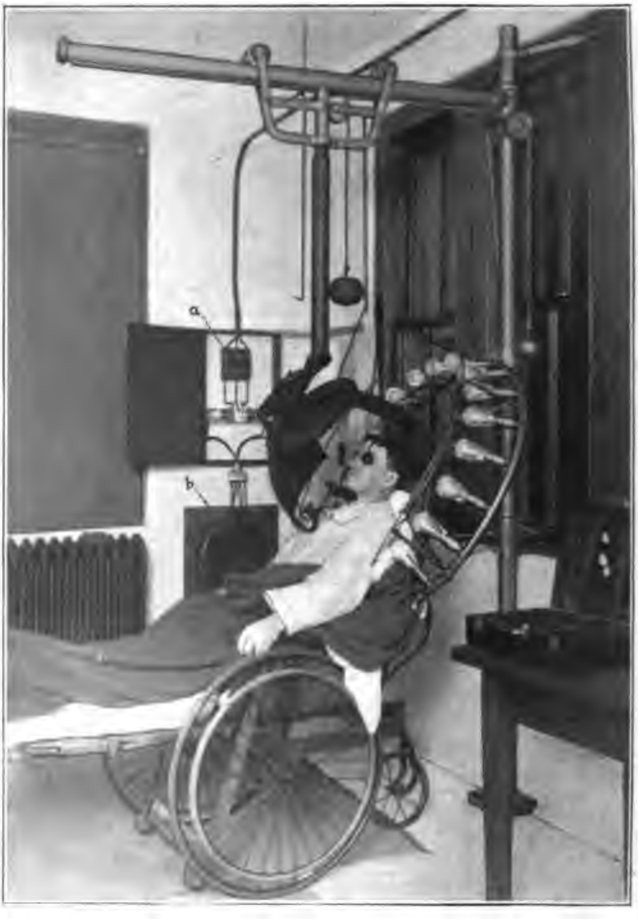

Fig. 4.—Adjustment of suspension perimeter for patient in wheel chair: *a*, switch board; *b*, rheostat.

By use of these devices the perimeter may be easily moved forward or back, up or down, swung to one side, rotated or tilted to meet all of our requirements with respect to position. Any perimeter may be suspended in this way. The one we use is a very wide faced perimeter of special design which has been previously described.[2]

The illuminating device is also attached to the vertical portion of the crane, as shown in Figure 3. To make this apparatus a piece of 1 inch iron pipe 8½ feet long is bent to form an incomplete circle 3½ feet in diameter. The opening in the circle is wide enough (20 inches) to admit the back of a wheel chair. Holes are then drilled and taped at an angle of 60 degrees with the axis of the circle, to receive sixteen sockets for electric light bulbs at intervals of about 6 inches. This brings the source of light to lie in a circle of about 32 inches' diameter, the distance of each light from the center of the perimeter during working conditions being 30 inches. The electric lights are protected simply by two parallel circular wire guards running around on each side and a little in front.

This circular bank of lights is hinged at its upper midportion directly to a sliding sleeve (*k*) on the upright portion of the crane. The two lower ends of the bank are also hinged to a lower sleeve (*l*) but with the intermediation of two rods 2¼ feet in length so that as the lower sleeve is made to slide down while the upper sleeve is clamped, the bank of lights can be tilted forward to the desired angle and fixed in position by clamping the lower sleeve (Figs. 1, 2, 3 and 4). However, when both sleeves are free, the bank hangs vertically and can be easily raised or lowered, being counterweighted over the pulley (*m*) on the upright portion of the crane.

In connection with this apparatus, I have also designed a Bjerrum screen (Fig. 5), which is placed directly across the room at a distance of 3 meters or less if desired. The screen can be used with the greatest ease after the visual field has been taken by simply pushing the perimeter to one side, and propping up the patient's head somewhat, if in the reclining position. Artificial illumination from the perimetric lights is a great help, since a large screen such as we use is diffi-

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[2] Walker, C. B.: Arch. Ophth., 1915, **44**, 369.

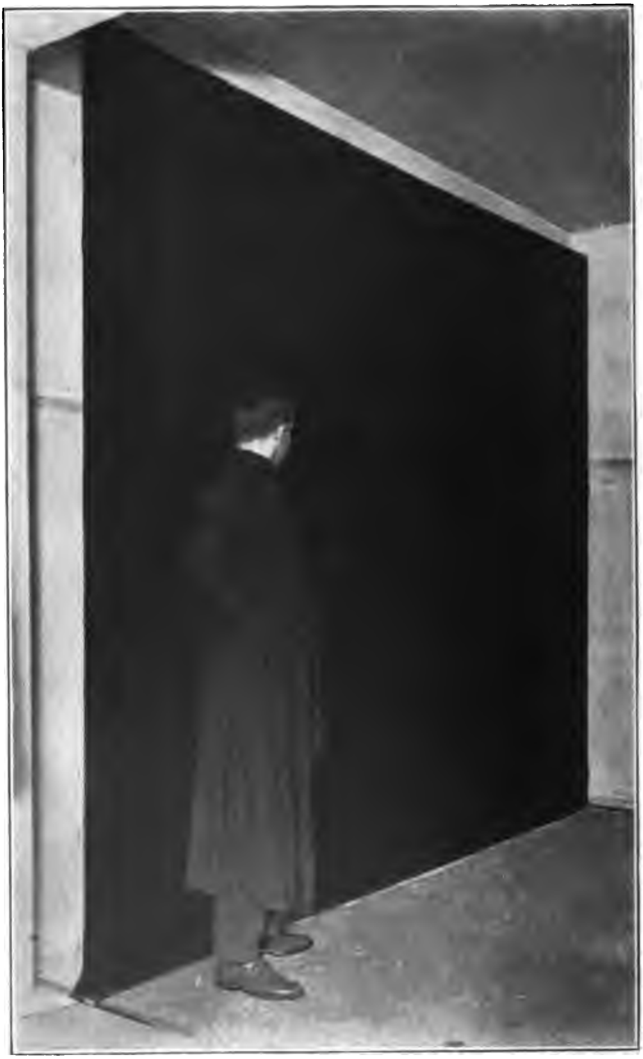

Fig. 5.—Large black screen serving for Bjerrum test and as a dark background when the perimeter is in use, black gown and gloves are worn by the examiner.

cult uniformly to illuminate in an ordinary room. The screen is made of light weight black canvas stretched over a frame measuring 9 by 11 feet. The frame is made of ¾ inch pipe having at the bottom short (18 inch) extensions at right angles to the screen, giving sufficient base to maintain a firm upright position. The canvas overlaps the frame and is laced taut behind by stout cording. The screen may be moved about the room and is readily demountable if it is necessary to move it to another room.

The examiner wears a black gown and gloves as shown in Figure 5, and, standing close to the screen, is able to see the lines of circles drawn on the screen representing the field at 2 and 3 meters' distance. The patient is not confused by these lines, since they are drawn with a soft pencil, and can be well seen only by the examiner. The lines for 3 meters are solid, those for 2 meters are broken. Three meters is the distance used for the most part, since only the very smallest visual angles (below 3 minutes) are tested on the screen, the larger angles (3 minutes and more) being readily tested on the perimeter by use of fine disks previously described.[2] The fixation point is slightly above the level of the patient's eye in order to get a sufficient field of screen below. The error on this account is negligible, since most of the measurements are under 30 degrees from the center.

ILLUMINATION

In a previous paper I have already stated my objections to the use of transilluminated (if I may use that term) test objects as a method of accurate perimetry. Briefly they may be stated as follows: It is necessary to work in the dark in order to control retinal dark adaptation phenomena which are not constant for half an hour or more. During the entire field examination this dark adaptation must be maintained constantly. Diffusion and dispersion of light rays in transit of the vitreous lead to confusion in determining the boundaries of the field. The size of the pupil may vary with the distance of the transilluminated test object from the center. The central fixation light and the test light may produce after-images. But, worst of all, the patient's eye cannot be observed in the dark as to fixation, and a mechanical perimeter is necessary to make the record. With the mechanical perimeter we cannot be sure of our records in the dark, nor can we use the range of disk-sizes necessary for a complete examination, as stated in the paper already mentioned.

With transilluminated test objects and mechanical perimetry precluded, we have left the possibility of closely imitating good daylight on the plain perimeter. Daylight, that is, skylight or cloudlight, may be closely imitated by strongly transilluminated milk-glass. And our original idea was to use the new nitrogen bulbs (75 watts) for this purpose; but it was soon found that, although they could be used, the heat developed by them, when used in sufficient number, was considerable. However, certain helpful data were obtained before they were changed.

From the switchboard (Fig. 4 *a*) the lights can be controlled in intensity through a wide range by use of a theater dimmer (*b*). The lamps are connected through this dimmer in two circuits, alternate lights being on separate circuits. Either circuit, or both together, can be separately controlled through the dimmer. It was found that sixteen of these lights are considerably more than are needed when not dimmed, but when they are dimmed to about the strength of skylight the "white" character of the light is lost, and reddish tints are more noticeable.

Accordingly it was decided that the rheostat is to be used only to determine, in the first place, how much light is required to approximate daylight, and later only for small adjustments. When the desired amount of light is thus determined, as will be explained later, it is duplicated by trying light bulbs of various wattages in the circular bank, with the rheostat out of circuit. Further adjustment cannot be done until daylight illumination of the perimeter had been carefully studied as a standard of comparison. This work may be outlined as follows:

CALIBRATION OF DAYLIGHT AND ARTIFICIAL ILLUMINATION OF PERIMETRIC TEST OBJECT

It was necessary first to provide a fairly accurate photometer of small size so that it would not itself block off illumination from the test objects. Also it should be possible to use the photometer when the test disks are at any point on the perimeter. Further, the observer's eye should be covered as little as possible so that the compensating devices of light adaptation and pupillary reaction shall be practically the same as in the patient's eye during field examination.

After considering several kinds of photometers, it was decided that a narrow wedge which could be moved vertically before the eye would best meet the requirements.

The light transmitting properties of a true wedge can be well imitated by proper exposure of photographic plates. Such wedges have been used by astronomers and Dr. Williams for measuring small or weak lights. Figure 6 shows an extemporized arrangement with which plates of sufficient uniformity for our purposes have been made. A 5 by 7 camera is fixed to a table in such a position that the slide of the plate holder can be drawn by the horizontal screw of a Killiam suspension apparatus. Any small windlass device will be just as satisfactory, since with a little practice one can develop a very uniform winding motion.

The exposure starts as soon as the slide leaves the end of the plate holder, since the shutter is left open, and ends when the shutter is closed at the moment the slide is out, the camera being pointed somewhat out of focus toward a white uniformly illuminated wall or screen. It was soon found, however, that uniform motion of the screw did not give a sufficiently short scale, no matter what the speed. If the speed, however, was increased from a very slow winding motion, at first, to a very rapid motion at the finish, a wider range was obtained. But if in addition to the increasing speed the diaphragm of the camera is gradually closed during the withdrawal of the slide by an assistant, a scale which is short enough, or even too short a scale, may result.

A variety of plates were made with these different exposures and then cut into strips 1 cm. wide. While no single strip gave us exactly the desired scale, a combination of two or more strips selected by trial gave a very satisfactory photometric wedge, since small variations in density were thereby averaged. With the glass side turned out and a marginal binding of adhesive or gummed paper, a handy little instrument was obtained (Fig. 7, reduced one-half size).

A satisfactory wedge for our purposes having been selected and mounted, there remained the problem of calibration. Here again selection of a suitable method was necessary. The use of a point source of standard light and the square of the distance ratio was unsatisfactory, as was also the use of the stellar magnitudes used by astronomers. The reason for the failure of

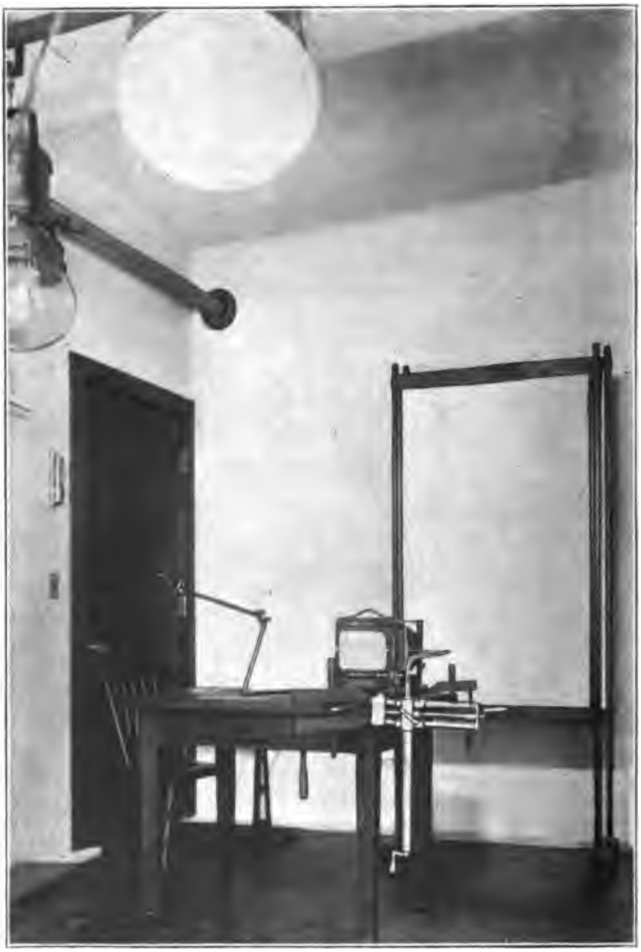

Fig. 6.—Arrangement used to make exposures for photographic wedge plates.

these methods, I think, is really a retinal phenomenon well shown in Tables 1 and 2. Here it is notable how fast the reading decreases as the size of the disk decreases, although the illumination per unit of area is constant. This was noted roughly before the calibration was done. As the object becomes punctuate in size the readings become more uncertain until finally the point is reached at which the normal central scotoma begins to interfere. These factors make it more difficult to build up a scale from a point source as a standard, than to build down from an illuminated disk on which it is much easier to make a reading.

TABLE 1.—CENTRAL ILLUMINATION OF PERIMETER BY BRIGHT MIDDAY LIGHT AND BY CLOUDY DAYLIGHT *

Disk Diameter	Averages of Bright Days, Best Light		Light Failure on Afternoons of Ordinary Cloudy Days (Averages)						
	Noon	10 a.m. and 2 p.m.	2 p.m.	3 p.m.	4 p.m.	5 p.m.	5:30 p.m.	6 p.m.	6:30 p.m.
40 mm.	0.75	0.73	0.67	0.63	0.50	0.41	0.35	0.30	0.20
20 mm.	0.74	0.72	0.65	0.60	0.49	0.40	0.35	0.27	0.18
10 mm.	0.73	0.71	0.63	0.58	0.48	0.38	0.33	0.25	0.15
5 mm.	0.71	0.69	0.61	0.56	0.47	0.37	0.30	0.22	0.13
2.5 mm.	0.63	0.60	0.57	0.51	0.45	0.35	0.28	0.17	0.10
1.2 mm.	0.52	0.50	0.48	0.45	0.40	0.30	0.20	0.11	
0.6 mm.	0.43	0.41	0.39	0.36	0.31	0.21	0.10		
0.3 mm.	0.31	0.30	0.28	0.28	0.22	0.10			
0.15 mm.	0.20	0.19	0.17	0.16	0.12				

* Tables 1 and 2 present a comparison of central perimetric illumination by daylight (general average) and by artificial illumination of different strengths.

TABLE 2.—ILLUMINATION POSSIBILITIES (CENTRAL) WITH VARIOUS LAMPS AND CIRCUITS

Disk Diameter	1 Circuit 60 Watt Lamps	2 Circuits 60 Watt Lamps	1 Circuit 40 Watt Lamps	2 Circuits 60 & 40 Watt Lamps
40 mm.	0.66	0.75	0.64	0.70
20 mm.	0.65	0.74	0.63	0.69
10 mm.	0.64	0.73	0.62	0.68
5 mm.	0.63	0.70	0.60	0.67
2.5 mm.	0.55	0.63	0.53	0.60
1.2 mm.	0.48	0.52	0.44	0.50
0.6 mm.	0.38	0.40	0.33	0.39
0.3 mm.	0.27	0.30	0.24	0.28
0.15 mm.	0.18	0.21	0.16	0.19

A consideration of our difficulties fairly suggests that the full moon in a cloudless sky would make an excellent standard for many reasons. It is diskiform, fairly uniformly illuminated, and of size comparable in visual angle to some of the disks to be examined. It is more strongly illuminated than any of our disks as used, so that the "lunar unit," as I shall call the strength of full moonlight illumination, must be divided preferably decimally to give the desired scale for use on perimetric disks.

The division of the "lunar unit" was accomplished in the simplest manner by combining ten strips from a plate of such strength that the full moon observed through them could be blanked out at some point as they were drawn past the eye. This point was determined in the same manner on the wedge which we wished to calibrate.

Since all the ten strips in the combination first described were of exactly the same density at the point at which the moon was blanked, we assumed that each strip represented one-tenth of a "lunar unit" at that point. If one of these strips is taken and the wedge to be calibrated is moved at right angles to the strips at the point mentioned, a place is found at which the moon is just blanked through the combination of strip and wedge. This point will obviously represent 0.90 lunar unit on the wedge. Next, two strips being taken, the point on the wedge representing 0.80 lunar unit was found; and by repeating the process, the wedge was divided into tenths of a lunar unit. The distance between each tenth was then arbitrarily divided into tenths so that our photometric wedge was finally calibrated in hundredths of the lunar unit, as indicated in Figure 7, which is drawn to scale.

Although the photometer described is not the most accurate, it has all the accuracy necessary and possible to apply under the conditions of observations by the patient. The results obtained with it are satisfactory and easily obtained. In taking the readings the observer seats himself at the perimeter with the eye at the center of the perimeter and observes the disk to be tested through the wedge held vertically before the eye. The wedge is slowly moved until the disk is just blanked out. A slight motion of the disk may be made at this point to assist the observation as the disk is made to appear and disappear several times until checking readings are obtained.

With this simple device a great number of observations were easily and rapidly made on the various sizes of test objects, both centrally and peripherally placed on the perimeter. Observations were made in all kinds of daylight, from morning until night, and in all sorts of weather conditions. Likewise observations were made with artificial illumination alone and with combinations of various conditions of daylight and various grades of artificial light.

To reduce the mass of data obtained to the smallest possible space, we find that we can refer to the light of any type of dark day, rainy, snowy, etc., as being equal to the light at some particular time between afternoon and dusk of any average day during which we have studied the light every half hour or so until dark.

Thus Table 1 shows the failure of light on an average bright, although short winter day. At noon the light is best, but for two or three hours before and after, the light is almost equally as good. On our scale when the readings are above 0.60 for the large disk and 0.50 for the 5 mm. disk, light adaptation seems to compensate to such a degree that the fields are satisfactory. The difficulty at this point is that it will not be maintained long enough to do much in case it is late afternoon of an ordinary day.

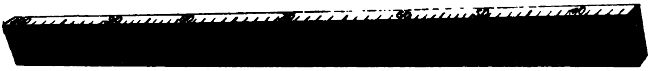

Fig. 7.—Drawing to scale of the completed photographic wedge, showing calibration in terms of "lunar unit." Reduced ½ size.

As failure of light continues beyond this point, the smallest disks begin to be thrown out of commission; and although the larger ones can be used, their fields are contracted. Thus the effect of light failure on the size of the field varies inversely with the size of the disk.

The weakened daylight of bad weather is apt to measure close to or less than the lower limit of usefulness mentioned above. While the larger disks can still be used under these conditions without great error, owing to the compensation of dark adaptation of the eye, the fields for the smaller disks both on the perimeter and on the Bjerrum screen are usually considerably reduced. One circuit if light of 40 or even 25 watt tungsten lamps will bring such light up to a satisfactory working strength. Since the testing with objects of small visual angles is most valuable in modern perimetery, the use of weakened daylight should not be tolerated when it is so easily brought up to a satisfactory working strength by addition of the artificial illumination of a few electric light bulbs.

The average central reading obtained by average daylight on the normal or 5 mm. disk has been found to be short 0.67 on our scale. Other disks will give readings according to their size, as indicated in the tables. This degree of illumination is, of course, readily obtained artificially by use of the rheostat and strong light. But by trying lamps of various wattages, it was found that when eight 60 watt frosted tipped tungsten lamps were used in one circuit while seven 40 watt and one 60 watt lamps were used on the other circuit, the full strength illumination met our requirements. Table 2 shows the illuminating possibilities of 40 and 60 watt combinations. Since each circuit has a separate switch, three degrees of illumination are available without the rheostat. One circuit or the other alone may be used to strengthen weakened daylight, either late in the afternoon or in bad weather. In worse light, both circuits will be used. It is notable in the table that doubling the illumination does not double the readings due to light adaptation phenomena.

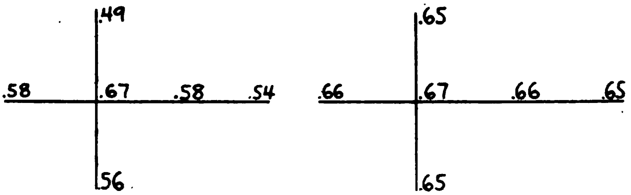

Fig. 8.—Comparison of illumination on principal points of perimeter by average daylight and by equivalent artificial illumination. Compare Tables 3 and 4.

Thus far I have considered the illumination of the central portion of the perimeter. Daylight illumination falls off considerably in the region from 60 to 90 degrees from the center because of the disadvantageous angle at which the light falls on the disk in this region. Table 3 shows several observations, at different times, on the 5 mm. disk at characteristic points on the perimeter in average daylight.

In this respect artificial illumination has a decided advantage, as shown in Table 4. The peripheral readings under these conditions fall off a negligible amount. It must be noted, however, that these readings are all taken without the eccentric adjustment possible with our perimeter. If we use 20 or 30 degrees of eccentric fixation, we have almost perfectly uniform illumination with artificial light in spite of the incompleteness of the circular bank, where it accommodates the patient's chest. The readings in the latter table serve also to show what degree of accuracy may be obtained after some practice with the photometer used, repeating readings checking usually within two hundredths.

TABLE 3.—ILLUMINATION OF PRINCIPAL POINTS ON PERIMETER BY AVERAGE DAYLIGHT *

Position	Average Daylight						General Average
Centrally..........	0.67	0.65	0.68	0.63	0.69	0.70	0.67
60° laterally........	0.58	0.57	0.57	0.54	0.50	0.62	0.58
90° laterally........	0.54	0.48	0.56	0.49	0.57	0.58	0.54
60° above..........	0.48	0.46	0.49	0.45	0.50	0.54	0.49
60° below...........	0.58	0.56	0.55	0.50	0.58	0.61	0.56

* Tables 3 and 4 present a comparison of illumination on principal points of perimeter by average daylight and by equivalent artificial illumination. Compare Figure 8.

TABLE 4.—ILLUMINATION OF PRINCIPAL POINTS ON PERIMETER BY ARTIFICIAL LIGHT

Position	Atificial Illumination						General Average
Centrally..........	0.66	0.67	0.68	0.67	0.69	0.66	0.67
60° laterally........	0.66	0.65	0.67	0.66	0.66	0.65	0.66
90° laterally........	0.65	0.65	0.66	0.64	0.64	0.66	0.65
60° above..........	0.64	0.67	0.65	0.64	0.65	0.64	0.65
60° below...........	0.66	0.65	0.65	0.66	0.65	0.65	0.65

Under artificial illumination of this type, the colors seem to give practically the same readings as in daylight, though it may be added that we find examination with the minute disks and smallest visual angles will usually give all the evidences obtainable with colors, especially now that we have given up color interlacing as a valuable aid to the diagnosis of increased cerebral tension. Spectroscopically the difference between the colors illuminated by daylight and by this method is practically negligible, being much less than variation from week to week due to soiling and fading, and quite within the limits of variation in colors one may always find in different offices and clinics.

CONCLUSIONS

1. An overhead perimetric suspension apparatus such as described has the greatest possible range of service.

2. Artificial illumination arranged to imitate daylight has proved to be a perfectly satisfactory, complete or partial, substitute for daylight.

3. Artificial illumination is superior to daylight in uniformity, in constancy, in availability and in control.

MEMORANDA

MEMORANDA

CONICAL CORNEA, OR ANTERIOR MYOPIA *

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This subject, last brought before the section in the valuable symposium by Burnett, Sattler and Hermann Knapp, seventeen years ago, is of great scientific and practical interest, and our knowledge of it is still fragmentary. It has broad relations with other pathologic conditions of the eye and with more general problems of nutrition. The phrase "anterior myopia" is suggestive of relations to the larger class of posterior myopia and the process through which the great majority of cases of myopia develop. Both keratoconus and posterior or axial myopia arise from the pathologic distention of the sclerocorneal coat. In their production, states of general nutrition and local conditions both share, but to quite different extents. Axial myopia has been the subject of extended and thoughtful study, especially by our colleague, Dr. S. D. Risley. The succession of events, eye-strain, uveal congestion, scleral softening and distention, and passage of refraction from hyperopia to myopia have been often watched. Especially has astigmia been noted, as an important factor in the production of eye-strain; the eyes passing, as Risley has phrased it, "from hyperopia to myopia through the turnstile of astigmatism."

The use of the eyes for near work is also recognized as a very general condition of the causation and progress of myopia. General diathetic diseases have also been considered to cause myopia. Batten[1] made a strong argument for the connection of myopia with

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* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June, 1917. Publication rights reserved by the American Medical Association.

[1] Batten: Ophth. Rev., 1892, p. 1.

general disease, and reported seventeen cases in support of this view, mostly of myopia arising in connection with cardiovascular disease. The share of general impaired nutrition in causing myopia has not been so well demonstrated as the share of near eye work and strain from astigmia, but it seems necessary to assume such a factor to account for the fact that in many patients astigmia, eye-strain and retinochoroidal hyperemia leave undiminished hyperopia, while others become less hyperopic or myopic.

In the production of keratoconus the same factors may be concerned, but with far different relative importance. In anterior myopia, conditions of lowered general nutrition seem to be of first significance; anemia, acute general disease, chronic diathetic diseases, and impaired nutrition from many causes seem clearly associated with the beginnings of conical cornea. These may from the first cooperate with eye-strain, and later certain mechanical factors perpetuate and increase the trouble; but conical cornea rarely, if ever, begins when the patient is in robust general health. It is easy to see why the nonvascular cornea should especially suffer from lowered nutrition; while the most vascular portion of the sclera at the posterior pole of the eye should be most involved in a process, marked by active hyperemia. In axial myopia the brunt of the pathologic process falls near the posterior pole of the eye and near to the temporal side of the optic disk. The influences that produce keratoconus show little or no effect except toward the center of the cornea well removed from the vascular limbus. The beginnings of keratoconus are not closely associated with near work for the eyes, although after the defect has come into existence, and the eye is crippled for distant vision, the same vicious circle is established as in axial myopia; and the deterioration is likely to be more rapid and to go much farther because of the presence in keratoconus of high and variable astigmia.

The conditions under which keratoconus begins are often difficult to determine. But in all cases that I have investigated carefully in this respect there has been a clear history of some antecedent severe impairment of nutrition.

One patient had suffered from extreme epistaxis; another from many attacks of epistaxis resulting in anemia; another had suffered from marked anemia from other causes, and three others first noticed defective vision while recovering from typhoid fever. One began after a severe attack of pleurisy. Others traced the beginning of the trouble clearly to scarlet fever and measles, although no history of special ocular inflammation at the time could be obtained, and there was no evidence of keratitis. A woman of 40 came out of two years of invalidism with astigmia of 5 and 6 D. incapable of perfect correction, although there was no evidence that her sight had been defective before that. A poorly nourished girl rapidly developed conical cornea at puberty.

This importance of generally depressed nutrition in causing keratoconus is also illustrated in the fact that most cases are bilateral, thirty-one out of forty-eight. Of the remaining seventeen, one patient had lost one eye probably from conical cornea, and the operations done for it; and in six others there was evidence that the eye, which was not counted as having conical cornea, had at one time been disturbed by the same process, but had soon regained a nutritive equilibrium retaining good vision with moderate astigmia. That is, of forty-eight cases, thirty-eight were really in the beginning instances of binocular disturbance. The importance of impairment of general nutrition in caus- keratoconus seems certain.

THE MECHANISM OF KERATOCONUS

Plaut[2] reported a case of conical cornea in which the affected part of the cornea was greatly thickened, and experimentally produced in rabbits a condition resembling conical cornea in which the membrane was greatly thickened. But the great mass of evidence indicates that thinning as well as softening of the tissue occurs so that it yields before normal or even diminished intra-ocular pressure.

Salzmann[3] reports examination of a keratoconic eye in which the thinnest part of the cornea, the apex of the cone, was 0.17 mm. in thickness, one-fourth or one-fifth the normal. He cites seven other reports of similar observations in which the apex of the cornea was found thinned to one-half or one-third the normal thickness. The ease with which the highly conical cornea can be indented by the lid margin, or altered in shape by lid pressure, make it certain that the essential change in keratoconus includes thinning of the cornea with distention.

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[2] Plaut: Klin. Monatsbl. f. Augenh., February, 1900, p. 65.

[3] Salzmann: Arch. f. Ophth. (Graefe's), **67**, 1.

The actual protrusion in a case of conical cornea is generally much less than commonly occurs in posterior myopia. A protrusion of 1 mm. makes a very marked conicity. My notes show no case of protrusion of the cornea of over 2 mm. Yet that lengthening of the anteroposterior axis of the eyeball would cause only 6 D. of myopia. Anterior myopia is to no important extent axial. It is preeminently myopia of curvature (Fig. 1). The protrusion rarely involves the whole cornea. It often affects little more than one-half the area. In a few chronic cases of gradual development the whole cornea is altered in shape, and in some others the protrusion blends so gradually into the conicity of the cornea that the appearance suggests involvement of the whole cornea in the pathologic distention. Often the pathologic bulging is distinctly marked off from the normal corneal curve. Generally the apex of the cone is situated below and to the nasal side of the center of the cornea, often as much as 2 or 3 mm. from the center. I have never noted it exactly at the center. This eccentric bulging gives the high astigmia that marks all cases of keratoconus. The center of the protrusion may present a fairly regular spherical curve, although usually it does not. But this center is so small that the light admitted through it is a very small proportion of that entering the pupil;

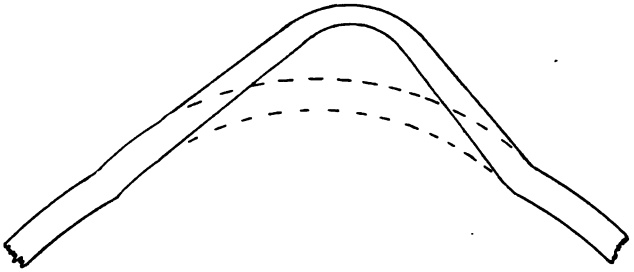

Fig. 1.—Diagram representing bulging of conical cornea of 2 mm. with thinning of apex.

and it may be so enormously myopic as to be far beyond the limits of correcting glasses or any possible usefulness in vision.

ASTIGMIA

Generally the apex of the cone does not come in front of the contracted pupil. The patient is compelled to see through one side of the cone and so has to contend with high astigmia. In the direction of a line radiating from the apex of the cone, the cornea is relatively or actually flattened. In a direction at right angles to this, the tangent of a circle having the apex as a center, the curvature is progressively increased as the apex is approached. Thus arises the high regular astigmia which with irregular astigmia characterizes the refraction of conical cornea. Of forty-five cases of keratoconus given optical correction, all had marked astigmia. The amounts of regular astigmia noted in these seventy-nine keratoconic eyes are given in the accompanying table.

AMOUNTS OF REGULAR ASTIGMIA IN SEVENTY-NINE KERATOCONIC EYES

Diopters of Astigmia	Number of Eyes
From 1 to 2	1
From 2 to 3	1
From 3 to 4	11
From 4 to 5	13
From 5 to 6	24
From 6 to 7	10
From 7 to 8	7
From 8 to 9	7
9	1
10	2
14	1
21	1
Total	79

Almost as characteristic as the high degree of regular astigmia is its variability from day to day, or test to test, under variations of light; and its tendency to change from year to year, in amount, and to a less degree in direction. The astigmia as indicated by the glass preferred also varies greatly from the curvatures of the corneal meridians as shown by the ophthalmometer. Take the following case under observation thirteen years, while passing through college, medical school and hospital internship:

Case 1.—L. G. W., aged 19 when first seen.
Nov. 6, 1903:
Right, Ophthalmometer + 4. cy. axis 120°
Lens — 3.50 Sph. ◯ + 2.50 cy. axis 153°
Left, Ophthalmometer + 3.50 cy. axis 60°
Lens — 5. ◯ + 3. cy. axis 10°

Dec. 26, 1908:
Right, Ophthalmometer + 4. cy. axis 140°
Lens — 3.25 ◯ + 0.75 cy. axis 160°
Left, Ophthalmometer + 4. cy. axis 65°
Lens — 4.50 + 2. cy. axis 5°

Aug. 29, 1910:
Right, Ophthalmometer — 4.50 cy. axis 130°
Lens — 3.75 ◯ + 3. cy. axis 170°
Left, Ophthalmometer + 4.45 cy. axis 60°
Lens — 4.50 ◯ + 2. cy axis 5°

Feb. 28, 1914: This patient's refraction changed with the use of pilocarpin.
Right, without: — 3.75 cy. axis 86° = 5/10 partly
With pilocarpin: — 0.50 ◯ — 3.50 cy. axis 110° = 5/6 mostly
Left without: — 5.50 ◯ + 3.75 axis 5° = 5/6 partly
With pilocarpin: —5.50 ◯ + 3.75 axis 5° = 5/6 mostly

March 2, 1914: Without pilocarpin:
Right — 0.50 ◯ — 3. cy. axis 95° = 5/12 partly
Left — 5.50 ◯ + 3.50 cy. axis 5° = 5/6 mostly

March 6, 1914:
Right — 2.75 cy. axis 95° = 5/6 mostly
Left — 5. ◯ + 3.25 cy. axis 180° = 5/6 mostly.

July 3, 1916: The eyes now became less variable and still required:
Right — 3. cy. axis 87°
Left — 5. cy. ◯ + 3.25 cy. axis 180°

For reasons given below, the close correction of such astigmia, at least to the extent of securing the best vision, and the keeping of the correcting glasses closely adapted to the eye, is of great practical importance.

EFFECTS OF LID PRESSURE

The effort to get the best vision is instinctive and persistent. It prompts the patient to try all sorts of experiments. The presbyope goes through the "trombone performance." The patient with uncorrected astigmia twists his head until he looks through his glasses obliquely in a way that makes them give the greatest assistance; the myope with too weak glasses looks through them obliquely to increase their strength, getting all the theoretical disadvantages of a full correction with some very important practical ones added. The myope without glasses partly closes his eyes, to lessen the circles of diffusion, thereby getting from the Greeks the name for his defect, which it retains today.

The patient with keratoconus, especially if it be largely myopic, is likely to resort to similar pressure to overcome, so far as possible, the disadvantageous curvature of the cornea. The long recognized "nipping" of the lids not only narrows circles of diffusion; it can also alter to a marked degree the corneal curvature, especially when the cornea is thinned and softened.

Case 2.—Miss G. E. F., aged 34, could change the curvature of her cornea equivalent to 1 D. change of refraction without closing the lids enough to prevent watching the ophthalmometric images. The effect was always to diminish the curvature in the horizontal meridian and increase it in the vertical meridian. The latter, however, was neutralized by the stenopaic effect of narrowing the palpebral fissure. Her cylinders, which were.

Right — 6.50 axis 120°
Left — 11. axis 120°

varied as much as 1 D. either way in frequently repeated tests, and as much as 15 degrees in the directions of the meridians chosen. The ophthalmometer reading indicated

Right — 5. cy. axis 80°
Left — 5.50 cy. axis 155°

at repeated observations.

Observations on other patients show that the usual effect of "nipping" the lids is that given above: to lessen the curvature in the direction of the palpebral fissure and increase it at right angles thereto, diminishing the myopia in the former and lessening the effect in the latter meridian. An unusual way of making such changes in the corneal curvatures is illustrated in the following case:

Case 3.—A. M. H., a schoolgirl, aged 12, had the following vision and refraction:

Right 4/27 partly — 4. sph. ⊃ + 1. cy axis 95° = 4/4
Left 4/100 and with — 9. sph. = 4/20

While not wearing glasses, she found she could bring up her vision so that she could see the blackboard by dragging on the outer canthus and upper lid of her right eye with the tip of a finger, as shown in Figure 2. In this way she brought up vision to 4/7.5 partly.

This patient was seen regularly at intervals of from twelve to thirty months, and by the time she was 19 her myopia had increased 2 diopters.

CASE 4.—K. F., man, aged 27, in 1903, had scarlet fever when 14, and was sick for a year afterward, from which period he dated his poor sight, which had gradually increased. He had high conical cornea. His corneas were almost clear, showing a very slight general haze, and the ocular fundus was normal. The ophthalmometer showed:

Right + 7. cy. axis 130°
Left + 10. cy. axis 80°

The following gave him the best vision:

Right + 5. sph. ⊃ — 8. cy. axis 75° = 4/9
Left — 6. cy. axis 80° = 4/40

He was not wearing glasses, having been unable to get any that helped him. Vision with either eye without lid tension was probably about 4/100, but the instant his attention was directed to the letters, a curious distortion of the whole face occurred with lid tension that brought his vision up to 4/20. The change is shown in Figures 3 and 4.

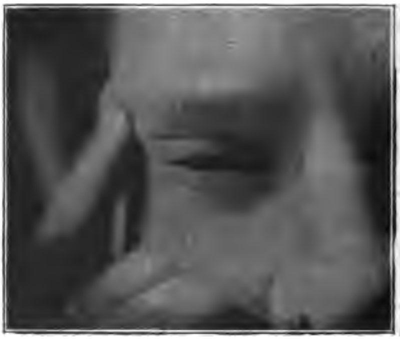

Fig. 2.—Corneal curvature modified by lid pressure produced by traction with tip of finger near the outer canthus.

The apex of the cone was below the edge of the 4 mm. pupil in each eye, and the lower part of each pupil (half for the right and two thirds for the left) was myopic. The upper part of each pupil was hyperopic. In his attempts to see (Fig. 4), the lower lid was pressed hard against the eyeball and stretched so that the edge of the lid went straight across the middle of the pupil. He was given correcting lenses, and warned of the importance of getting entirely out of the habit of compressing the eyeball with the lids.

At the end of eleven months he returned with corrected vision right 4/5 and left 4/40, and his corneas entirely clear. He

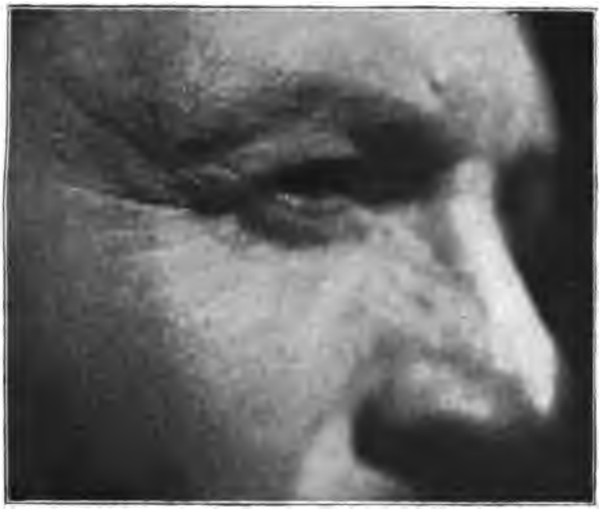

Fig. 3.—Face of patient at rest. Note wrinkles about the eye of a man of 27.

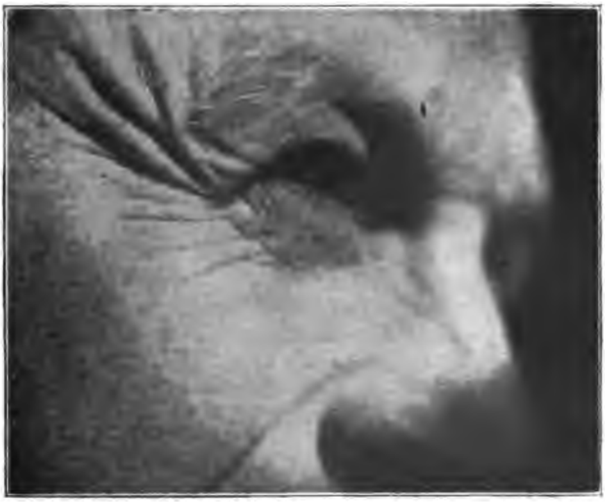

Fig. 4.—Face distorted by strong contraction of orbicularis to improve vision by lid pressure on the cornea.

had given up the habit of lid tension so completely that he could reproduce the effect very imperfectly and with special effort. It was eight years before he could come again wearing the same glasses, which now required change, and the left eye had developed high myopia with choroidal absorption.

Right + 4. sph. ⊃ — 8. cy. axis 72° = 4/5 partly
Left — 4. sph. ⊃ — 8. cy. axis 140° = 4/18

Since than I have not seen him, but have heard from him that the sight of his left eye "is almost gone, and the right eye is in bad shape."

The following case shows how even the posterior distention of axial myopia may not save the cornea from protrusion, or how the malnutrition and softening of the coats may involve both the posterior and the anterior pole.

Case 5.—B. G. M., girl, aged 15, a bright student devoted to music, and strenuous in all she undertook, but anemic and "nervous," was brought to me for her eyes, Sept. 21, 1916. She had been wearing glasses since 8 years old, and now required them strengthened to:

Right + 0.75 sph. ⊃ — 1.25 cy. axis 175° = 4/4 plus
Left + 0.62 sph. ⊃ — 1.25 cy. axis 5° = 4/4 plus

There was little choroidal disturbance, but the optic disks were red and slightly hazy. The ophthalmoscopic readings were:

Right + 1.50 cy. axis 90° added to 43.5 D.
Left + 2. cy. axis 90° added to 44. D.

There was some conjunctival hyperemia, burning and itching, in addition to the headache for which she came. She was under my care for four months and left with all symptoms relieved. June 19, 1912, she returned, having been under good professional care in Chicago and elsewhere. The strenuous educational process had been supplemented by social engagements. The ophthalmometer now showed:

Right + 1.25 cy. axis 90° added to 44. D.
Left + 10. cy. axis 100° added to 49. D.

The left eye was clearly suffering from conical cornea. A — 10. cy. axis 10° gave it vision of 4/50.

She next came, Sept. 14, 1912. The ophthalmometer showed:

Left + 9.50 cy. added to 52. D.
Lens, Left + 3. sph. ⊃ — 16. cy. axis 145° = 4/15 partly.

No marked change in the right eye, but

Right + 0.62 sph. ⊃ — 1.12 cy. axis 168° = 4/5 partly.

Oct. 4, 1916, she came once more broken down in health, highly anemic, listless, hopeless, and almost blind. She had been under treatment by various oculists in other cities.

There was a history of operations, corneal ulcers, and finally enucleation of the left eye. Vision in the right was less than 1/100; she was wearing a compress on it much of the time, and using eserin. It had suffered from an "ulcer" last winter. The ophthalmometer showed but little regular astigmia with a corneal curve of over 70 D., corneal radius about 5 mm. A —30 D. sph. lens gave vision of 9/100. There was a nebula near the center of the cornea. The use of a bandage was almost stopped, being occasionally used for pain, the eserin was continued, and everything done to build up the general health of the patient.

Jan. 11, 1917, the eye felt better, and the iris was of good color and structure. The ophthalmometer showed:

+ 6 to + 8 cy. axis 80°, added to 60 or 65 D.

Hot bathing of the eye has been substituted entirely for the bandage. The eye feels worst in the morning. The patient is to keep the head elevated.

Cases 6 and 7.—F. B., aged 18, and his sister, aged 17, both came for conical cornea, with the history that every member of the family wore glasses. They were both students, the brother then in college. In all three eyes the area of protrusion was comparatively small and situated below the center. The brother's correction and vision was:

Right + 4.50 sph. ⌢⌣ — 7. cy. axis 90° = 4/4 partly
Left + 4. sph. ⌢⌣ — 7. cy. axis 100° = 4/15 partly

After eight years now living on a ranch these are:

Right + 3.50 sph. ⌢⌣ — 7.50 cy. axis 90° = 4/5
Left — 5. sph. — 7.50 cy. axis 85° = 4/12

The sister had only the right eye affected. She had vision:

Right + 1. ⌢⌣ — 4. cy. axis 38° = 4/5
Left + 1. sph. ⌢⌣ — 0.25 cy. axis 90°

After 4 years she showed:

Right + 2. sph. ⌢⌣ — 5. cy. axis 55° = 4/4 partly
Left + 1.75 sph. ⌢⌣ — 0.37 cy. axis 65° = 4/4 plus

These patients have taken proper care of their eyes, although living about 200 miles away so that they could be seen only at long intervals. The same is true of the following case:

Case 8.—Jan. 29, 1910, S. J. G., aged 19, high school student, dated his poor sight to typhoid fever five years before. The eyes had not grown worse since. Both corneas were conical, the apex of each cone being fairly central, and the reflections of the rings of Placido's disk fairly circular. The centers of the pupils showed with the ophthalmoscope a myopia of 20 to 30 D., and the margins of the dilated pupils in the direction of the radii hyperopia of 15 to 20 D. The ocular fundus was normal in each eye, so far as could be determined. The patient was put on the regular use of pilocarpin. Lenses given:

Right —15. sph. ⌢⌣ —8. cy. axis 20° = 4/30
Left —10. sph. ⌢⌣ —5. cy. axis 20° = 4/30

He was seen six months later with vision: Right 4/30, left 4/12.

Sept. 12, 1914:

Right + 3. ⌢⌣ —6. cy. axis 25° = 5/15 partly
Left + 6. ⌢⌣ —1. cy. axis 180° = 5/15

Jan. 26, 1917: He comes several hundred miles to be seen once.

Right + 4. ⌢⌣ —6. cy. axis 25° = 5/15

Left shows keratitis, hazy with facet at apex of cornea 1 mm. in diameter, no staining with fluorescein. He has completed school and college, and is now teaching school. He has used the pilocarpin continuously, but has not used his glasses sometimes during summer vacations.

In this paper no attempt has been made to give any complete account of conical cornea or complete histories of any of the forty-eight cases on which it is based. All of these cases have shown marked conicity of the cornea in some projection, asymmetrical except in Case 8. None of them has shown any marked choroidal disease or atrophic crescent except Cases 1 and 2. In the series of cases from which the forty-eight were taken, there were thirty-nine cases of myopia with 3 D. or over of astigmia, and seventeen cases of hyperopia, with astigmia of 3 D. or over. None of the forty-eight patients, except Case 5, were subjected to operation, and all the worst cases have been included above.

The points to which attention is directed are:

1. Keratoconus arises from yielding of the cornea to intra-ocular pressure during a period of impaired nutrition, commonly due to general disease.
2. It gives rise to curvature ametropia, about which the ophthalmometer and the shadow test give little information of value for the selection of glasses.
3. The subjective tests with lenses give widely variable results; and a decision as to the best lens is reached only after many trials, under varied conditions influencing the pupil.
4. It is extremely important that glasses should give the best vision under the conditions under which they

will be used without lid pressure, which is to be carefully avoided.

5. The treatment should include:

Every effort to build up and sustain nutrition.

The continuous use of a miotic in the worst cases, usually pilocarpin.

The avoidance of softening the cornea by any form of bandages.

Under proper care operative treatment will rarely be needed.

MEMORANDA

A NEW OPERATIVE METHOD FOR THE RELIEF OF ADVANCED CASES OF KERATOCONUS

WITH REPORT OF TWO CASES *

MEYER WIENER, M.D.
ST. LOUIS

Conical cornea was observed by Demours as early as 1747, and has been described by many authors since that time. There has never been any satisfactory explanation as to its production or cause. It is known that it is more frequent in females than in males, and is generally first noticed between the twelfth and fourteenth years of life. The probability is that some disturbance of internal secretion is the most potent causative factor.

Many operations have been devised for the relief of this condition, none of which has given entirely satisfactory results The earlier surgical attempts to relieve conical cornea were bent toward changing the refraction of the eye behind the cornea rather than to alter the cornea itself. In 1817, Sir William Adams advised breaking up of the crystalline lens by needling. Tyrrell suggested a still different procedure, that of performing a peripheral iridectomy, on the theory of there being less deformity toward the margin of the cornea than in the center, and consequently a peripheral pupil would be of advantage. Crichett modified this a little later by permitting the iris to prolapse, and tying a ligature around it, thus distorting the pupil. Frequent puncturing of the periphery of the cornea has also been resorted to for many years. Von Graefe suggested the greatest advance for the relief of this condition by proposing that the epithelial coat of the apex be shaved off and then cauterized with silver nitrate; finally the floor of the resulting ulcer was

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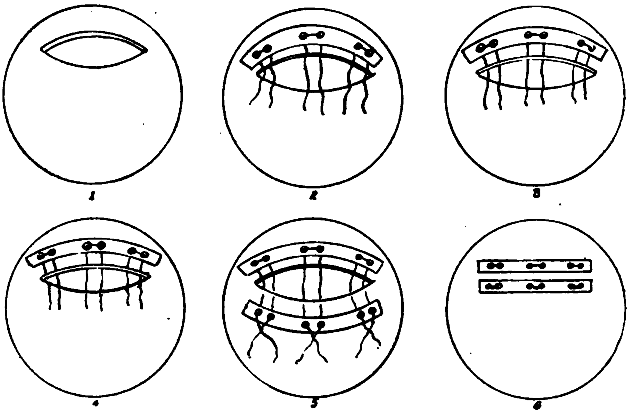
* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June, 1917. Publication rights reserved by the American Medical Association.

punctured, the object being to try to bring about scar contraction with resulting flattening. Bowman had previously excised a disk of corneal tissue from the apex with a trephine, but without any great success. A number of cases in which he excised an elliptical piece were reported by Bader. To prevent prolapse of the iris he passed horse-hair sutures through the cornea, previous to making the excision, afterward tying them over the edges of the wound. This operation has probably been the one most frequently advocated of those procedures which we might term purely surgical. The use of the electric cautery, or frequent punctures of the apex with a needle, being more simple and less dangerous, are the methods most often used today, when anything at all is advised. Recently a case of marked flattening has been reported from the use of the high frequency current applied to the apex of the cone.



Details of operation: 1. Elliptic incision of cornea near margin. 2. Gold strip with double-armed sutures already in place ready to be passed through peripheral margin of cut. 3. Sutures passed through peripheral margin of wound. 4. Sutures passed through central margin of wound. 5. Sutures passed through second gold strip. 6. Gold strips in place after completion of operation.

The great objection to excision of the apex of the cone, or of a peripheral part of the cornea, has been the almost invariable prolapse of the iris into the wound with the sudden gush of aqueous, with its resulting infection, or irritation from an extensive leukoma adherens. The method which I am proposing is an excision of the corneal tissue in such a manner as to avoid iris prolapse. This I have succeeded in doing, and with fairly good visual results.

As the cornea near the apex of the cone is so thin as to preclude the probability of a successful dissection, I have elected to excise a segment near the periphery, as best suited to the method. The idea is to excise a segment of the cornea, including as nearly as possible its entire thickness, without puncturing Descemet's membrane, and then suture the wound. Necessarily there as an unusual tension on the stitches which would cause them to tear through almost immediately unless some extraordinary means were employed. This difficulty is met by tying the sutures over thin gold plates, on the same principle as that employed in bringing together the gap in cleft palate. This method of suturing was described by me at the 1915 meeting of the Academy of Ophthalmology and Oto-Laryngology.

Gold strips 0.005 mm. in thickness and 1 mm. wide are used, with holes 1 mm. apart, and just large enough to permit the passage of the smallest curved eye needles. The length is cut according to the size of the wound to be sutured. An elliptic incision is made in the cornea near the limbus, with a small, sharp scalpel. The object is to go as deeply as possible without penetrating Descemet's membrane. The length is about 8 mm. and the width 3 mm.

The apex of the part to be excised is then picked up with a tiny sharp hook, and the resection carefully begun. The most important part of the dissection is to get a good start, as the apex of the ellipse can then be grasped with fixation forceps, and by putting the flap on the stretch, the layers of the cornea can easily be separated. This separation can be readily accomplished by following, with the point of the knife, the white line at the point of attachment of the flap to the cornea. By keeping the blade of the knife flat against the corneal surface, using only the tip, and alternately stretching and then separating, there is not much danger of entering the anterior chamber. Double armed sutures are then passed around the first gold strip through the small openings, then in turn through the central flap of the wound, through the limbus flap, finally through the openings of the second gold strip placed on the opposite side, and then tied over this second strip with one tie. The stitches are then alternately tied more firmly together until the wound is approximated. Linen threads are an advantage on account of their strength. The amount of tension which this form of suturing will withstand seems to be almost unlimited. If there is no infection they will not pull through, provided the technic is good. The technic is delicate and difficult, but can be acquired by any experienced operator with much practice and patience. It is essential that the bored holes shall be polished in order that the stitches may slide easily. I believe it to be an advantage purposely to puncture the anterior chamber at the periphery, away from the wound, after the sutures are all in place, and just before tightening and closing the wound, in order to permit easier approximation of the wound and facilitate healing with lessened tension. The plates are left in position, with comparatively little irritation, for eight or nine days. They are easily removed by simply cutting the loop over each gold plate, when the thread readily pulls through.

The following is a brief history of the patient on whose eyes this operation was performed:

M. S., girl, aged 15, first came to the Jewish Hospital dispensary for treatment, April 30, 1915. She had a very pronounced case of conical cornea in both eyes with ability to count figures at 7 feet with the right eye and 18/100 with the left. Her refraction was carefully determined, but no improvement of any value could be secured, minus lenses making letters clearer, but not bringing up the visual acuity by measurement. She was put on epinephrin chlorid, 1:1,000, three times a day, as we had seemingly had some good results in mild cases of keratoconus and keratectasia with this treatment, as recommended by Pontius. It did not help, however, and, Feb. 23, 1916, she was admitted to the Jewish Hospital, and the right eye operated on two days later. March 6, the stitches and plates were removed, and, March 12, patient discharged from the hospital. There was considerable photophobia and conjunctival redness for many weeks after the operation, but these slowly subsided.

Sept. 12, 1916, visual acuity had reached 18/100 in the right and fallen to fingers at 7 feet in the left. As the operated eye was considerably better than the left, or unoperated one, the patient begged to have the same thing done for the left.

She was admitted to the hospital, Oct. 9, 1916, and operated on, October 11. A segment was excised from the lower quadrant, as in the right eye. March 7, the stitches and plates were removed, and the patient discharged from the hospital, Oct. 29, 1916. November 28, the visual acuity was

18/100 in the right and 18/200 in the left. The visual acuity in the right has remained stationary, and in the left, March 8, 1917, had improved to 18/75.

A peculiar phenomenon about this case is that while the patient asserts that a —4.0 D. S. to a —7.0 D. S. lens will improve each eye very much, she cannot be made to read further. There is a linear scar on each cornea in the lower quadrant which can readily be demonstrated but which does not disfigure the patient and would not be noticed by a casual observer. I believe that there will be still further improvement with time, but if this should not develop, I shall advise excision of another segment. The patient is willing.

MEMORANDA

OBSERVATIONS ON HEREDITARY SYPHILIS IN PATIENTS WITH INTERSTITIAL KERATITIS *

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BOSTON

For the past four years, it has been my privilege to study cases of interstitial keratitis in connection with the ophthalmologists of the Massachusetts Charitable Eye and Ear Infirmary, and especially with Dr. George S. Derby, who first suggested the association. We have had two objects in view: first, to learn something about the relationship between interstitial keratitis and syphilis, and, second, to learn something more about treatment and prognosis.

Our work has been encouraged and assisted by the Perkins Institute for the Blind.

For this paper, it has been possible to utilize two series of cases: one of 1915, of 152 cases, and another of the spring and summer of 1916, of eighty-five cases, and certain other cases not included in either of these groups.

The diagnosis of interstitial keratitis in all these cases, excepting a very few diagnosed by the ophthalmologists of the Boston Dispensary, has been made by the ophthalmologists of the Massachusetts Charitable Eye and Ear Infirmary, so that the premises are well established. It was early shown that ophthalmologists themselves do not always agree in the diagnosis. As services in the infirmary change, we occasionally receive a patient with the diagnosis of interstitial keratitis from the incoming physician who has been treated by the outgoing physician as something else, probably phlyctenular keratitis. It is not very unusual to find that the present attack has been preceded by previous ones which have been named phlyctenular

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by the same physician who now recognizes an interstitial keratitis. Interstitial keratitis develops sometimes quite slowly. Three successive different diagnoses in three successive visits were made on one of our patients. These differences in diagnosis must have something to do with the different beliefs in the matter of causation, and with uncertainty in treatment.

It is equally apparent that there is often a difference of opinion among dermatologists and children's physicians as to the diagnosis — and wonderful reluctance to make a diagnosis — of hereditary syphilis.

With differences among eye doctors as to the diagnosis of the eye lesion on the one hand and differences among clinicians, on the other hand, as to the constitutional condition — whether syphilis is present or not — it is no wonder that doubt should arise as to the relationship between interstitial keratitis and hereditary syphilis.

The words of Mr. Hutchinson[1] are worthy of special attention: "Interstitial keratitis, in its typical form, is always a consequence of syphilis and is in itself sufficient for a diagnosis. It must, however, be carefully diagnosed." To which should be appended, The diagnosis of syphilis must be made with equal care.

Our first study in these cases in which the ophthalmologist has diagnosed interstitial keratitis has been to determine the existence of syphilis. For whatever uncertainty exists as to the mutual relationship of these conditions, the syphilographer and pediatrician must be equally blameworthy with the ophthalmologist.

The recognition of hereditary syphilis in cases which present all the characteristic stigmata is one of the simplest problems, but children often present themselves with but a single symptom and that poorly marked. In the latter cases, the diagnosis is one of the most difficult problems of medicine, though of late years it has been much simplified by the Wassermann reaction.

Diagnostic study of a child suspected of syphilis must be conducted along two lines — the study of the child itself and the study of the family of which it is a part.

The Wassermann reaction plays an important part in the diagnosis. To tie a rubber band about the upper arm and insert a sharp, hollow needle into one of the veins at the elbow is a simple procedure, but it is a frightful ordeal for some nervous or timid children. It is seldom advisable to do it by force at the first visit of such children. To frighten a child, before one has gained its confidence, too often results in preventing its further attendance. Nor is it always necessary. A positive Wassermann reaction in the parents or in brothers or sisters may answer every purpose, and clinical evidence is often sufficient to establish the diagnosis. A Wassermann reaction, however, is always desirable for future reference and because critical persons are apt to regard the work as incomplete if a Wassermann test has been omitted; but one should not allow himself to think that the Wassermann reaction is the only symptom of hereditary syphilis.

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[1] Hutchinson, Jonathan: Syphilis: Clinical Manual for Practitioners and Students, p. 75.

We have two series of Wassermann reactions. The first was done in part before the cholesterinized antigen was adopted. This series comprises fifty-three patients and it was strongly positive in thirty-six; moderately positive in three; doubtful in two, and negative in twelve.

The second series of Wassermann reactions comprises sixty cases — of these sixty cases all are positive. These sixty Wassermann reactions were part of the series of eighty-five patients seen during the spring and summer of 1916. Of the remaining twenty-five patients, three mothers are positive; one father is positive; five mothers are patients in the syphilitic clinic. In the sixteen cases remaining, the diagnosis was clinical, sometimes confirmed by roentgenoscopy. The Wassermann tests were all done with the cholesterinized antigen. There were eight that were marked "moderately positive," but the exact character of the reaction in every case cannot be determined from our records.

The "moderately positive" report in a patient who has no other evidence of syphilis cannot be accepted as proof positive of syphilis; but, occurring in a patient who has other signs, it is of great value. The Wassermann test, however, does not do away with the necessity for the clinical recognition of hereditary syphilis. One may find himself in a spot in which the Wassermann test is unattainable, there may be reasons why it is undesirable to inflict a dreaded pin-prick, or the result of the Wassermann test may need clinical confirmation, and the clinical diagnosis has the great advantage of being made at the moment and not deferred for hours or days, and in those cases in which the results of the serological examination is at variance with our expectations clinical accuracy is as necessary as accuracy in the laboratory.

Jonathan Hutchinson drew attention to the frequent occurrence in the same child of interstitial keratitis and deformity of the upper central incisor teeth of the permanent set. These teeth are dwarfed, peg-shaped, notched and irregularly placed in relation to each other. Since Mr. Hutchinson's description, they have been known as hutchinsonian teeth. One may dare to vary the original description as follows: Like the child, these teeth are undeveloped. The middle lobe is wanting, making the characteristic notch; the cutting edge is narrow; the enamel does not always cover the whole tooth; as a whole, one or both teeth may be decidedly dwarfed and improperly placed, but all these imperfections are seldom found in any one tooth.

Mr. Hutchinson also pointed out the fact that deafness was also often associated with interstitial keratitis and deformed upper central incisors. To the combination of these three symptoms — interstitial keratitis, hutchinsonian teeth and deafness, Fournier has has applied the term "hutchinsonian triad.".

Mr. Hutchinson also mentioned another symptom which has been largely lost sight of:

> At the same time as the keratitis, the patients often suffered from chronic synovitis of one or more of the large joints. The knees are most frequently affected and there may be free effusion lasting for some weeks, but not often attended by much pain. Almost invariably, the effusion disappears and the joint is perfectly restored. These joint affections may occur either before or after the keratitis, and sometimes to those who never suffer from the latter.

In our cases the knees are frequently affected and symmetrically. The affection is simply an effusion of fluid into the knee joints with sometimes a thickening of the capsule without other symptoms. It is one of the characteristics we have learned to look for in each new case. In our first series of 152 cases, the occurrence in the same individual of interstitial keratitis and hutchinsonian teeth and deafness, or the hutchinsonian triad, occurred twelve times, while the coincidence of interstitial keratitis, hutchinsonian teeth and symmetrical synovitis of the knee occurred thirteen times.

Of our eighty-five cases of interstitial keratitis, in 1916, fourteen patients are reported as having hutchinsonian teeth and two additional have false upper central incisors "because their natural teeth were so imperfect." They ought to be included, making sixteen. Sixteen are also reported as having effusion in the knees.

Of the hutchinsonian triad — eyes, ears and teeth — there are six. Of the knee triad — eyes, ears and knees — there are five. Having eyes, ears, teeth and knees, there are four.

It is curious that so frequent a symptom should have been unknown to so acute an observer as Fournier. It can hardly be an accident that it has occurred so often in our cases. Interstitial keratitis, hutchinsonian teeth and symmetrical synovitis may prove to be as common a combination as the hutchinsonian triad.

One point to be noted about these knees is the fact that they show no change in the joint itself when submitted to Roentgen examination, though a thickened capsule or opaque synovial fluid may show a haziness about the joint. But, if the examination is carried beyond the joint, the bones of the lower leg often show characteristic changes of syphilis, and roentgenographic examination must be considered a very important factor in diagnosis of syphilitic children.

The blind and deaf make a most important group among the cases of interstitial keratitis. Deafness in these cases occurs in two forms: (1) an extension from the throat by the eustachian tube, in which the deafness is usually partial and not hopeless; (2) those cases in which the auditory nerve is affected. In the latter cases, the deafness usually comes on suddenly, is total, and, while not hopeless, is certainly very serious in its outlook. The care of these children, especially the latter group, is of the greatest importance, to prevent, if possible, their falling into the class of deaf, dumb and blind.

Fortunately, the majority of our patients with interstitial keratitis, who have become deaf, are only partially deaf and have practically regained their eyesight. Four are entirely deaf and deserve separate and individual notice.

There are eight who are only partially deaf and are not specially handicapped. Of the twelve deaf, five have also hutchinsonian teeth. One has the upper central incisors replaced by artificial teeth. Following are the histories of the four who are totally deaf:

Case 1.—P. E., a clean, intelligent girl, aged 17, and her youngest brother, live with an aunt. Her mother died in 1911 of "tuberculosis," according to report. The father deserted eight years ago. "He had been going down hill for years." The patient graduated from grammar school at 15½, and began to support herself as salesgirl, when she become "blind" for three months. Then her eyes improved and she became totally deaf. She first came to our clinic in May, 1916, and her face at that time was a picture of hopelessness. The change in her expression after admission to the Horace Mann School for the Deaf was simply wonderful.

Case 2.—I. M., girl, came from a family in which the father was syphilitic at the time of marriage and gave the disease promptly to his wife. He died in January, 1916, in the Boston State Hospital for the Insane, of general paresis, after three years of sickness. Mrs. M. had seven miscarriages followed by two living children, the patient, now aged 10, and her sister, aged 6. Mrs. M. and the two children are patients at the Massachusetts General Hospital with syphilis. The two little girls are also at the Eye and Ear Infirmary with interstitial keratitis and I. M. is a patient in the Ear Department and at the Horace Mann School for the Deaf and Dumb, later at Randolph. She has had trouble with her legs and knees and was in a plaster cast at the Homeopathic Hospital. Irene's vision is recorded as O.D. 20/200; O.S. 10/200, Aug. 8, 1916.

Case 3.—D. G., girl, aged 7 years, had trouble with her eyes for a year and a half before we saw her. She lost her hearing suddenly in April, 1916. Her vision was very low. She "will not answer to any vision tests." With her loss of sight and hearing, she changed, not unnaturally, from a sweet and lively child to a very bad-tempered one. Her father reports that since she came under treatment she had seen and heard better, but sufficient time has not elapsed to tell how much improvement there is to be.

Syphilis apparently entered this family after the birth of the fourth child. The first died at 2 years of pneumonia. The second, third and fourth are living and well. The fifth died at 3 months with a rash; the sixth is living, well but small; the seventh and eighth were miscarriages; the ninth is D., our patient; the tenth was a miscarriage; the eleventh and twelfth are said to be well. The thirteenth is expected.

Case 4.—J. M., boy, aged 12 years, was in the Eye and Ear Infirmary during the summer of 1915, where he was treated by Coley's serum. In September, 1915, he went to the Clark School for the Deaf at Northampton, but was discharged in October because of deficient eyesight. He was referred to us in December from the Eye and Ear Infirmary. He is totally deaf. His father planned to send him to the School for the Deaf at Hartford. The father is reported as saying that he cannot manage him. On the other hand, all the nurses and everyone knowing the boy in the infirmary during the summer of 1915 loved him and found him obedient. He always liked to "help" the nurses and patients. He is probably an illustration of the necessity of providing an occupation for these children, who, like other people, can be happy only when they are busy.

Certain symptoms often associated with syphilis are quite conspicuous by their absence in those groups.

Of ulcerations and open sores there are none, though scars of infantile lesions are common.

Destruction of nasal bones, with falling-in of the nose and destruction of the soft parts, has not occurred in any of this series. Bones of the nose have been affected, but not destroyed.

There is in attendance at the clinic one girl with this deformity, but she is not afflicted with interstitial keratitis. This probably represents about the proportion of nasal deformity. The symptom is so noticeable that it has become the characteristic of syphilis in the popular opinion, but it is actually of rare occurrence.

Operation for adenoids have been very frequent in the group; sometimes the operation has been repeated a second and a third time. Some of these operations, apparently, have been done for symptoms due to nasal deformity rather than true adenoids.

The condition of our patients as regards the nervous system is worthy of more careful study than we have been able to carry out. A large number seem somewhat deficient mentally. Many of them are in a lower grade in school than their age demands. That is largely due to their inability to attend school, but some of them are certainly deficient. One has been an inmate of Wrentham School for the Feeble Minded; two or three have brothers in the same or similar institutions. Some form of chorea is quite common, and several have had epileptiform seizures.

The coincidence of tuberculosis in some of these patients presents occasional difficulties. That these two diseases may occur together is undoubted; that they are mistaken for each other is also true. They cause difficulty in the diagnosis of eye conditions as they do in skin, bone and joint troubles. The family histories often mention tuberculosis in relatives of our patients and raise the doubt as to the possibility that the alleged tuberculosis was really syphilitic.

Great interest centers in the cases in which interstitial keratitis has occurred in adults. They raise several questions. In the first place, are these cases really hereditary syphilis, or are they acquired? If they are hereditary, is this the first manifestation of the disease, or is it a recurrence? It has long been a disputed question as to whether hereditary syphilis may first show itself in adult life. These cases help us to answer this question. The consideration of individual cases is of interest.

Case 5.—Man, aged 21, has his first attack. The diagnosis of syphilis is made sure by a strongly positive Wassermann reaction. In addition, he shows certain symmetrical changes on both fibulae which coincide with similar changes in other syphilitic children. He was for some time a telegraph messenger. He is the elder brother of the next patient.

Case 6.—Girl, aged 16, also has an interstitial keratitis and a strongly positive Wassermann reaction. The patient is extremely "nervous." She is subject to dizzy spells which suggest epileptiform attacks. She is inclined to melancholia. The family history is noticeable. Out of eight pregnancies, there are but four living children.

Case 7.—Man, aged 18, a patient of Dr. F. M. Spalding, has had repeatedly recurring attacks of iritis. In this case, the family history of parental syphilis makes certain the diagnosis. In addition, the young man has hutchinsonian teeth. He has been subject for a long time to "dizzy spells" which suggest epileptic attacks. His blood was not taken for a Wassermann test, as the diagnosis was absolutely certain.

Case 8.—Woman, aged 20, has evidently a hereditary case. Here the interstitial keratitis is a recurrence. The diagnosis is made probable by the scars at the angles of the mouth, and confirmed by the strongly positive Wassermann test.

Case 9.—Man, aged 21, has well marked hutchinsonian teeth. He has a very irritable, nervous system, and has had headaches all his life. In his case, the hereditary character is shown by the combination of hutchinsonian teeth and interstitial keratitis, and a history which seems to point to trouble all his life. There was no record of a Wassermann test in his case.

Case 10.—Woman, aged 34, the oldest of the patients, has an interstitial keratitis which must be at least the third attack. She was treated for what, from her history, would appear to have been the same trouble with her eye at 6 years of age and at 9. Her Wassermann test is negative, but the family history justifies the diagnosis.

Case 11.—Woman, aged 21, with interstitial keratitis, had trouble with her eyes when she was in the third grade at school. The Roentgen ray shows specific periostitis of the tibiae. She is now totally deaf. Of her family, there were eleven pregnancies; four only are living. There is a story of intemperance, etc., on the part of her mother.

This represents the oldest of our patients. It will be seen that all have evidence of previous disease, though the first one mentioned bore no external evidence and had no remembrance of pain or tenderness in his bones although the roentgenograms revealed evidence of old bone disease.

The study of the family of which the child is a part is a matter of great importance, but often of considerable difficulty. These children are often orphans. Some have grown up in orphan asylums or almshouses. Even under the best of conditions, it is seldom possible to gain all the desired information at the first visit. It is, I believe, not advisable to begin the examination by asking the father or mother if they ever had syphilis. It puts them on their guard, and even arouses their suspicions. In many cases it closes the conversation. In very few of these cases has that question been asked at all. After confidence has been established, information will be given freely which would not have been obtained by obnoxious quizzing. Information is sometimes more easily obtained from an uncle or an aunt than from the parents.

To learn that one of the parents has died of tabes or general paralysis is just as valuable information as to be told that the parent had syphilis; the establishment of that fact shows syphilitic parentage.

Habitual drinking or frequent drunken sprees on the part of either parent is a very suspicious circumstance. I cannot help feeling that some of the effects on offspring often attributed to alcohol may occasionally be due to syphilis acquired during a drunken orgie.

Excessive mortality in infants and young children in the family is very suspicious of syphilis but is not in itself conclusive. Another cause for the numerous deaths may, of course, exist. Induced abortion may give a story not unlike that of syphilis. Hereditary syphilis is seldom named as a cause in the death certificate, and then only in the returns from charitable institutions, not in private practice. Marasmus as a cause of death appears frequently in the death roll of syphilitic families, and it seems not unlikely that many of the deaths attributed to summer diarrhea have syphilis as an additional factor.

A child with an interstitial keratitis whose father was a drunkard and died at an early age in an insane asylum, whose advent in the family has been preceded by stillbirths and early deaths from marasmus or other causes, may be considered syphilitic without hesitation.

Some of the difficulties which may arise in finding the constitutional cause and the value of family history in our cases are well illustrated by a single case.

Cases 12 and 13.—A girl, aged 7 years, was among the patients sent from the Eye and Ear Infirmary. The diagnosis of syphilis in her case was plain enough. The difficulty came in her brother, the only other child, a boy of 15 in whom no sign of the disease was evident and who was said by his mother to have been always well. While the little girl was still under treatment, the boy was attacked by a keratitis in one eye and soon after in the second eye. Had this boy been seen alone before his sister, a diagnosis of syphilis would have been difficult, if not impossible.

It is an important question whether or not the disease in these children with interstitial keratitis is communicable. It was emphasized in the following case:

Case 15.—The school nurse felt that B. G., a girl, was a source of danger to the other children, and succeeded in keeping her out of school. The school physician took pains to inform himself about her and favored her continuing in the school as harmless, but the publicity given the child made school distasteful to her. The case was recently brought to the attention of the Commission for the Blind, which has done what it can to care for the girl, medically and to further her education, but it is too late.

There is a tendency on the part of charitable organizations to refuse assistance to children with even a suspicion of syphilis, from a conviction that they are dangerous to other children. The danger in these late cases is greatly exaggerated, if it exists at all. In this class of cases, any affection of the skin or mucous surfaces is almost unknown; nor are lesions of the tongue or palate at all frequent. Without such lesions, communication of disease is hardly possible, and clinically we have no evidence that disease has ever been conveyed by these patients. There is no reason to exclude them from school.

TREATMENT

It is a common belief that interstitial keratitis responds poorly to antisyphilitic treatment, and, in general, this is true; but it is not the whole truth, nor does it mean that antisyphilitic treatment is useless. The patients themselves usually respond readily and show marked gains in general condition. Occasionally an eye that is threatening changes for the better on the first administration of any one of the usual remedies. Occasionally, a similar improvement takes place on a change from one of the antisyphilitics to another. Dr. Morton Smith, of the Massachusetts General Hospital syphilitic clinic, believes that the earlier salvarsan is given the better the result. There have been some curious incidents in the treatment of our patients which are not easy to interpret but which certainly show that mere routine is not desirable.

Case 16.—E. T., of our last year's group, was a patient in the ward with knees affected by syphilis. While in the ward and under treatment but not salvarsan, she was attacked with interstitial keratitis. The addition of salvarsan to her medication was followed by immediate improvement in her eyes.

Case 17.—This year, there was sent to us from the Children's Hospital a boy who had an attack of interstitial keratitis while he was under treatment by salvarsan for other forms of syphilis. Salvarsan had been administered several times and in sufficient doses. He had been under treatment for six months before the interstitial keratitis appeared. Under mercurials alone he improved rapidly and was discharged from the eye clinic with normal vision.

In general, it may be said that a child or an adult with interstitial keratitis ought to be looked on as a case of constitutional syphilis with local manifestations in the eye. The eyes should certainly have the oversight of the ophthalmologist, but the sufferer should also be under the care of some one who will regard the child as a syphilitic and continue supervision after the eyes have ceased to need special treatment. The question that concerns us at this time is what constitutional treatment is likely to give the best results, so far as the eyes are concerned.

There is a serious difference of opinion in regard to treatment of cases of syphilis with interstitial keratitis among eye men in Boston and probably elsewhere.

One man feels that salvarsan is deleterious and does not wish his patients to have it. Another uses Coley's serum for some unexplained reason. Some have great faith in salvarsan and feel impatient if its use is delayed. Some wish constitutional treatment directed by a syphilographer; others resent his interference, while some, alas! are indifferent.

It may be said that, as a rule, salvarsan should be given as soon after the patient appears for help as can conveniently be done, in the hope of checking the local disease at once, which may sometimes be accomplished. This should be accompanied and followed by some form of mercury. Mercury with chalk is of great value in the case of children. It has great tonic qualities for heredosyphilitics.

Potassium iodid or some of its succedanea help in clearing the cornea after acute symptoms have passed. It is the fashion to decry potassium iodid to day. It may not cure, but clinically it certainly is of great value.

The value of food and hygiene must be recognized. Drugs are of little value to a patient who is insufficiently fed.

A vacation in the country will occasionally start an improvement in an obstinate case.

Treatment does not prevent involvement of the second eye.

I believe early treatment may have something to do with forestalling symptoms, but it is not possible to demonstrate it.

The value of a social worker in the care of these cases can hardly be overestimated. For the attainment of the best results, she is a necessity. We are disposed to find fault with patients who are not brought to the clinic with regularity, without recognizing the difficulty which the family experiences in carrying out our wishes. The social worker succeeds in finding the family difficulty and helping to adjust the patient to changed conditions during the time of sight diminution and in rearranging the life plan, if the injury is to be permanent.

Our social worker, for the past year, has interested herself in the school life of patients with interstitial keratitis and, among other items of interest, has brought out the fact that fifty children of school age have lost a total of sixty years of schooling.

In conclusion it may be said that interstitial keratitis bears a close resemblance to other symptoms of syphilis in that cases are not always absolutely characteristic. Our study tends to confirm the already quoted saying of Mr. Hutchinson that "Interstitial keratitis in its typical form is always a consequence of syphilis. It must, however, be carefully diagnosed" with the necessary addition that the syphilis must be diagnosed with equal care.

Constitutional treatment is not always followed by improvement in the eye condition, certainly not immediately. At the same time, brilliant results occasionally follow — often enough to encourage constitutional treatment even if the eye alone is regarded. The general condition of the child is almost always improved, sometimes wonderfully.

The study of the child with interstitial keratitis, as a social problem, often leads to good results as regards the family and the community; it discovers other members of the family in need of care, and in general tends to improve the family conditions and limit the effect of the disease. That it prevents in future offsprings further blindness cannot be positively affirmed, except in its general improvement of family conditions. It has shown some of the difficulties in diagnosis and why doctors sometimes disagree.

It may further be said that this study has led to an increased knowledge of hereditary syphilis and interest in it as a whole in the medical and social service departments of both hospitals.

MEMORANDA

INTERSTITIAL KERATITIS

WITH SPECIAL REFERENCE TO THE END-RESULT *

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BOSTON

The cases on which this study is based have been selected from the large series of persons with hereditary syphilis and interstitial keratitis who have been so fortunate as to come under the skilful care of Drs. Abner Post and C. Morton Smith[1] during the past five years.

Interstitial keratitis is one of the most studied of eye diseases. It can boast of a most voluminous literature, in which almost every phase of the process is exhaustively discussed. From the standpoint of history, symptomatology, pathology, experimental research and therapy, it has claimed the interest of many of the best ophthalmologic minds of the present and past. That not all of its problems are yet solved is due rather to their complexity than to a failure of competent men to attack them. One most important question has, however, received but scant attention, namely, an exact knowledge of the end-result. With that feature in mind, the study reported here is principally concerned.

A large majority of the patients were personally examined, and most of the remainder were seen by Dr. Alexander Quackenboss, chief of service of the Massachusetts Charitable Eye and Ear Infirmary. In a few instances, when neither Dr. Quackenboss nor I was on duty, other members of the staff kindly took the task on their own shoulders. To them, and especially to Dr. Quackenboss, I wish to make my grateful acknowledgment.

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* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June. 1917. Publication rights reserved by the American Medical Association.

[1] Formerly presiding over the syphilis clinic at the Boston Dispensary; more recently in charge of the newly established syphilis department of the Massachusetts General Hospital.

In the whole series, except in a very few instances, only cases were accepted in which the inflammation of the eyes had come to an end at least two years previously. Thus, the visual results obtained may be regarded as reasonably permanent, although we cannot bar out the possibility of some slight further clearing of the cornea in some cases, and in others deterioration of sight due to recurrence of the disease or to the development of myopia.

The whole number of cases observed here is ninety-six, comprising ninety-four in which the disease had occurred in both eyes, and two in which up to the time of the examination only one eye had been affected; thus, a total of 190 eyes are available.

Corneal Opacity.—By careful examination with oblique illumination, it was possible to note a corneal opacity of greater or less density in 168 eyes, while in fourteen none could be seen. This opacity varied from thick leukomas in a few cases to the finest possible haze in others.

Vascularization. — The examination for vessels in the cornea was made with the ophthalmoscope and a strong convex lens, after the pupil had been dilated as much as the condition of the eye would allow. In 186 eyes, vessels were found in 171 and were absent in fifteen. In some cases I have observed them after the lapse of many years, as has been noted by others. Whether or not avascular cases occur is a matter of some discussion. Von Graefe, Vossius, Gutmann, von Michel, Knies and Elschnig are in favor of it; while Fuchs, Saemisch, Galezowski and others believe that this is seldom or never the case. As a rule, the vessels persist for years. Hirschberg has observed them ten, fifteen and even twenty years after the disease, and believes, as does Silex, that they never disappear.

Bearing on this question, the following case is of interest:

A doctor, aged 69, who had been in very delicate health as a child, at the age of 14 had inflammation of both eyes lasting one year, with recurrence five years later. When 38 years old he was seen by Dr. O. F. Wadsworth of Boston. At this time corneal scarring was marked and there were many patches of choroiditis in the periphery of the fundi. When I saw the patient, Feb. 19, 1917, there were diffuse corneal scars of each eye. There were marked signs of old vascularization in the corneas. There were many patches of chorioretinitis in the periphery of the fundi.

V. R. —10. sph. —2.0 cyl. axis 90 = 1/20
V. L. + 7. sph. +1.0 cyl. axis 90 = 1/10

This case, therefore, shows unmistakable evidence of vessels in the cornea fifty-five years after the original inflammation.

Baas has reported a case in which no evidence of vessels could be detected clinically, and yet the histologic examination later showed their undoubted presence.

Iris.—As to the involvement of the deeper portions of the eye, we note the presence of posterior synechiae in sixty-two eyes. My experience, however, bears out that of Hoor,[2] namely, that in frequent instances the involvement of the iris and ciliary body bears but little relationship to the severtiy of the corneal process. Where the keratitis itself is of but average intensity, it is sometimes only with the greatest difficulty that dilation of the pupil can be obtained, while at times with a severe keratitis dilation is accomplished by very moderate instillations of atropin.

Lens.—In four eyes, slight opacification of the lens was left behind. Axenfeld has observed peculiar circumscribed opacities occupying the situation of previous posterior synechiae, and appearing as faint, star-shaped thickenings of the capsule, which show fine pigment deposits under high magnification.

Vitreous.—In eleven eyes, vitreous opacities were noted. In thirty-eight eyes, by reason of the corneal scars, or of the permanently contracted pupil, it was impossible to make a satisfactory examination of the deeper structures.

Choroid and Retina.—We have notes on the fundus examination of 148 eyes, and of these, eighty-one showed lesions of the choroid and retina (55 per cent.) mostly in the form of disseminated rounded lesions, usually situated in the equatorial region. That in some negative cases lesions existed forward of the equator is not to be doubted. The percentage of chorioretinitis recorded here is much higher than any I have come across in the literature. It should be said that the examination was made with the greatest care, with dilated pupil, and that special attention was paid to the periphery of the fundus.

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[2] Hoor: Die parenchym. Hornhautentzündung, Samml. Zwangl. Abhandl., 7, 788.

As it happened, the eyes were examined in two series. In the first, comprising eighty-eight eyes, forty-eight were positive, 54.3 per cent. In the second, of sixty eyes, thirty-three were positive, exactly 55 per cent.

In regard to the relationship of the fundus changes to the corneal disease, I feel that while in a certain number of cases of interstitial keratitis in which the involvement of the uveal tract is beyond the ordinary, fundus lesions may develop, yet in the majority of cases they appear independently of the corneal process and usually antedate it. It has been possible for us to observe in several instances the presence of such lesions in the choroid and retina in the uninvolved eye of patients with a beginning interstitial keratitis.

Vision. — With the exception of Igersheimer's article,[3] I have been able to find little or no definite information as to the visual results among the sufferers from this disease, a feature of the greatest importance. Our results are recorded in the two tables presented. All visions were taken under a mydriatic and with the appropriate correction.

TABLE 1.—VISION OF 161 EYES EXAMINED

No. of Eyes	Vision
32	10/10
17	7/10
18	5/10
13	4/10
25	3/10
14	2/10
17	1/10
25	less than 1/10

Table 1, which gives the vision of 161 eyes examined, does not truly represent the exact degree of disability in each case, as the two eyes must be reckoned together, for many children possessing one good eye get on practically as well in school as do those with two. In later life their disability consists in being barred from certain occupations and having a lesser factor of safety, when we take the normal chances of injury to the one good eye into account.

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[3] Igersheimer: Das Schicksal von Patienten mit Keratitis parenchym, Samml. zwangl. Abhandl., 1913, **9**, No. 4.

TABLE 2.—VISION OF BETTER EYE IN EIGHTY CASES

Number of Eyes	Vision
24	10/10
9	7/10
11	5/10
5	4/10
11	3/10
9	2/10
6	1/10
5	less than 1/10

In Table 2 the vision of the better eye in eighty cases is given. Taking the figures from the standpoint of education, Table 2 shows that twenty-four children would have the same chance as the normal child. Twenty-five more could study in the same classes with normal children, but would be handicapped, especially in choosing an occupation. Twenty, or possibly twenty-six, could be educated in defective eyesight classes, if any were available, or failing that would have to be referred to institutions for the blind, as would the remaining five. It should be noted, however, that as some of these children grow older and more intelligent, it may be possible to improve their vision somewhat more with glasses. On the other hand, it may be diminished by recurrence of the disease, or by the development of myopia, especially prone to occur in these cases. Myopia was noted in nineteen of our eighty cases, about 25 per cent. Igersheimer noted it forty-four times in 152 eyes, or 29 per cent.

TABLE 3.—IGERSHEIMER'S STATISTICS OF VISION IN ONE HUNDRED AND FIFTY-TWO EYES

No. of Eyes	Vision
7	10/10
11	7/10
16	5/10
32	3/10 to 4/10
24	2/10 to 3/10
34	1/10 to 2/10
28*	less than 1/10

* Five of these twenty-eight were blind.

For the purpose of comparison, Igersheimer's statistics of vision in 152 eyes are given (Table 3). A glance shows a considerably graver situation among these cases than do our figures. Of our 161 eyes, 42 per cent. have vision of $\frac{5}{10}$ or better; of Igersheimer's only 22 per cent. Forty per cent. of his cases had vision of less than $\frac{2}{10}$, and only 26 per cent. of ours; in seventy-seven cases determined, a loss of earning power in forty-three. In any event, whether his figures or ours are nearer right, no one can deny that the disease causes a visual economic loss that deserves consideration.

Etiology.—By the diagnosis "interstitial keratitis" I mean the typical cases of this disease. To quote the words of Jonathan Hutchinson, "Only typical cases of chronic diffuse keratitis must be chosen, for although the affection is unmistakable to the practiced observer in a great majority of instances, yet it has, like all other diseases, a border ground on which mistakes may be made." In my opinion, it is usually the border line cases that have caused the endless controversy as to the etiology.

In a certain small number of cases, another factor probably enters in. I refer to the coexistence of another corneal disease, usually phlyctenular keratitis. In a small number of the cases which I have observed, naturally excluded from the series on which this eye report is based, we find on the hospital records a diagnosis of the first disease, and at a later period the second diagnosis was made. We know that tuberculosis not infrequently occurs in hereditary syphilitic children, and it may not be too much to say that these children, especially the poorly nourished ones, are particularly liable to develop tuberculous lesions. I believe, therefore, that phlyctenular disease and interstitial keratitis can occur in the same person at different periods, and in making the ocular diagnosis in a doubtful case this possibility should be borne in mind.

The relation of interstitial keratitis to tuberculosis has never been definitely settled; the views of various authors differ markedly. In 107 cases Diez gave 42 per cent. as tuberculous. Von Michel once stated that 40 per cent. were of this nature, von Hippel[4] twenty-eight cases out of eighty, Enslin eight out of nineteen. In thirteen cases with a positive Wassermann reaction, Kummell obtained a positive general reaction to tuberculin. Elschlepp found seven similar cases. A. Leber, in eighty cases, found six surely tuberculous and four probably so. Hess is of the opinion, and to his observation we must lay great weight, that tuberculosis is a cause of interstitial keratitis. In a series of cases examined with tuberculin injections for diagnosis, he found several which gave a focal reaction in the eye. Clausen[5] has observed a similar case. The last named writer, after considering carefully the evidence, concludes that 90 per cent. of interstitial keratitis is due to syphilis, and that tuberculosis is the next most important cause, and that in a number of these cases both diseases are present, but that generally in such cases syphilis plays the important part in the production of the eye disease.

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[4] Von Hippel: Arch. f. Ophth., 42, 194.

To quote Jonathan Hutchinson again:

> I will not make so sweeping an assertion as that interstitial keratitis never occurs except in people of inherited taint, yet I cannot conceal from myself, and have no wish to do so from my reader, that such is my present belief.

Igersheimer, who perhaps has devoted as much attention to this disease as has any other ophthalmologist, came in 1913 to the same conclusion to which Hutchinson subscribed in 1858. And on the basis of the large series of cases which forms the groundwork of this communication, I am inclined to the same view, with the reservation that, in the light of our present knowledge, we must admit a small number of cases of the disease may be of other than a syphilitic origin.

Recurrences.—It is my belief that recurrences are considerably more frequent than existing figures show. Some ophthalmologists have held that recurrences seldom occur (Silex, Nimier-Despagnet), others that they occur sometimes (Fuchs, Vossius, Hosch), and Arlt and Gutmann that they are frequent. In a carefully followed series of sixteen cases, von Hippel found five with recurrence, 31 per cent. In eighty-seven cases, many of which were observed only a short period of time, he found but 17 per cent., as did Jakolewa, Brejski in 18 per cent. and Stephenson in 22 per cent.

In thirty-seven cases in which I have carefully gone into the question of recurrences, I have found positive evidence in fourteen (38 per cent.), and in three more recurrence was probable.

Will the treatment of hereditary syphilitic children in their early years prevent the development later of an interstitial keratitis?

Hochsinger's Experience. — Sixty-three cases of undoubtedly congenital syphilitic children were followed by Hochsinger and Kassowitz from four to twenty years; of these, twenty-two were followed carefully for eight years, after they had been treated energetically with mercury in very early life. Among this group there was not a single case of interstitial keratitis, deafness or hutchinsonian teeth.

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[5] Clausen: Arch. f. Ophth., **83**, 399.

The following cases occurred in my practice:

Case 1.—D. M., a boy with undoubted signs of hereditary syphilis, developed a paralysis of the third nerve of the right eye in the early months of life. As far as could be ascertained, his treatment up to the age of 4 consisted largely in the use of the iodids combined with inunctions. At 4 years of age he developed in this eye an interstitial keratitis of moderate intensity, which lasted for about five months. At this time he came under the care of practitioners thoroughly qualified in the handling of syphilitics, and was given thorough treatment with mercury over the succeeding four years. In 1908, then at the age of 7, and three years after the involvement of the right eye, he developed a mild interstitial keratitis in the left eye, which ran its course in about ten weeks and cleared up almost completely. Seven years later, in 1915, the vision in the left eye with a minus cylinder was 10/10—, the cornea showed a slight opacity, and a number of vessels in the cornea were to be seen.

Case 2.—G. V., boy, developed unmistakable active signs of hereditary syphilis soon after birth, and was given continued treatment with inunctions twice a day for two years and with mercury and chalk for a year more by his doctor. At the age of 9 months, he developed in one eye a uveitis with a small hypopyon. The ocular disease cleared up within a year, but general treatment was continued. Four years later he developed an interstitial keratitis of both eyes, of moderate intensity.

While cases like these are discouraging, I believe that they should in no way deter us from the energetic and long continued treatment of hereditary syphilitic children. Although we cannot, in the light of our present knowledge, influence markedly in many cases the course of the ocular inflammation, nor can we prevent the involvement of the second eye, yet we can and do produce improvement in the general condition and often in the mentality of our patients. It is well known that a positive Wassermann reaction is unusually persistent in these cases, but by adequate treatment of sufficiently long duration it can be made to disappear. Recurrence of the eye disease and other complications are certainly much less likely to occur, and if they occur at all, without the presence of active disease as evidenced by the Wassermann reaction.[6]

In conclusion, a quotation from Igersheimer may not be out of place:

> In the interest of the later career of patients with interstitial keratitis it is important to administer antisyphilitic treatment with the greatest energy, not only during the course of the ocular disease, but afterward from time to time as long as the Wassermann reaction is positive.

7 Hereford Street.

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[6] The literature up to 1911 will be found in the exhaustive articles of von Hippel, Hoor and Clausen, which have been freely used. Other communications referred to are:

Axenfeld: Ber. d. Ophth. Gesellsch., 1913, p. 261.

Wickerkiewitz: Ber. d. ophth. Gesellsch., 1913, p. 262.

MEMORANDA

PRESENT STATUS OF CORNEAL TRANSPLANTATION

SOME EXPERIMENTAL DATA *

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While this operative procedure has intermittently held the attention of many workers in the field of ophthalmology for over a century, to the present it has proved a failure, except in rare instances. A review of the literature on the subject will show to a fair degree the causes of failure and the main elements which might lead to success.

To Pollier de Quengsy, a French oculist, is given the credit of being the pioneer in this work. In 1789 he attempted to transplant a piece of glass into the center of the cornea, and from this time on other men, Nussbaum in 1856, Huszar in 1859 and von Hippel[1] in 1877, attempted the same thing, while Drummer in 1889 and Salzer[2] in 1899 tried celluloid, all with no success to speak of. Salzer reported a case in which the glass was retained for two and one half years, but it ultimately sloughed out, and this at least showed the great vitality and endurance of the cornea.

F. Reisinger, in 1824, was the first to attempt the transplantation of the cornea from one animal to another, by means of a transcorneal keratoplasty. Half of the cornea cleared up in two and a half days, but later the eye sloughed out. Schon, in 1827, denied the practicability of this work, but did no experiments to prove his assertion. Both Dralshagen and Diffenbach,[3] in 1831, were unsuccessful and decided that if

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* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June, 1917. Publication rights reserved by the American Medical Association.

[1] Von Hippel: Arch. f. Ophth., 1878, **24**, 235-256.

[2] Salzer: Arch. f. Augenh., 1909 **115**, 226; Ber.. ü. d. Versamml. d. Ophth. Gesellsch.., 1911, **36**, 244.

[3] Diffenbach: Ztschr. f. Ophth. (Ammon's), 1831, **1**, 172.

the foreign cornea did adhere it would soon become turbid and unserviceable.

Bigger,[4] in 1835, took up the problem with more vim than success. He first operated on the leukomatous eye of a gazelle by means of a complete section of the cornea, and reported a good result. Later he operated in the same manner on a timber wolf and thirteen rabbits. His chief difficulties were movements of the animal at the time of operation, and sepsis. His original account itself is worth the reading, from the standpoint of subtle humor, and an appreciation of the difficulties under which the earlier experimenters worked.

H. Power,[5] in 1872, took up the work along a somewhat different idea, and his experiments with a cork borer and sharp steel punches were the forerunners of the later trephine operations. His results were bad, and due, he said, to the lack of precaution and poor technic. Among many other investigators on the subject, von Hippel led a school that used the trephine. His was a mechanically operated instrument and there was great difficulty in controlling the depth of the cut and the sterility of the instrument. His results were not good, mainly because he attempted heteroplasty. Others followed von Hippel, using his trephine, among them Zirm,[6] who grafted the cornea of a child, aged 11 years, to that in a case of total opacity of the cornea having vision of shadows. The result was that six months later the patient had vision 3/20 with plus 5.00. One year later the patient died, and as the eye was not examined the depth of the leukoma was not known. Fuchs, in 1894, operated in eleven cases and, on account of the opacity of the graft and the penetration of new vessels, he gave up the project.

Magitot[7] lately took up the trephine method, but he used an instrument much different from von Hippel's. His was a modification of Eliot's trephine which would cut a graft approximately 5 mm. in diameter to the required depth, and after repeating the operation on the eye to be transplanted, he transferred the grafts. They were held in place by a nasal and temporal corneal stitch over the graft. Atropin was instilled and the eye bandaged for forty-eight hours. He used not only fresh tissue, but also infants' eyes which had been submerged in aseptic serum for some time, washing them in Ringer-Locke solution after taking out, and grafting as before. He reports that the grafts grew, and that the opacity was not great. This most certainly is an example of the great vitality of corneal tissue.

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[4] Bigger: Dublin Jour. Med. Sc., 1837, **11**, 408-417.

[5] Power, H.: Rep. Int. Ophth. Cong., 1872, **4**, 172-176.

[6] Zirm: Arch. f. Ophth., 1880.

[7] Magitot: Compt. rend. Soc. de biol., 1911, **36**, 369; Ann. d'ocul., Paris, 1916, **153**, 369, 417.

Probably the most spectacular operation of this type of work was one in which Chimanowski attempted a total corneociliaryplasty, if the term may be used. He operated on a patient, aged 20, who had perception of light, and removed the whole cornea and the ciliary body without touching the muscles. The graft was placed in physiologic sodium chlorid solution for three hours, and then sutured to the prepared host by ten suture points. Healing took place and the sutures fell out. On the twenty-fifth day one part of the cornea was clear and the other grayish, vision being light perception. On the fiftieth day no suture line was visible; the anterior chamber was 2 mm. deep, the iris was visible, and an astigmatism of 37 D. was reported. On the seventh month there was some organization, and the vision was fingers at 18 inches, tension being 18 mm. One year later there was a sensitive cornea tension of 23 mm. and there was opacity of the globe; but no atrophy was found. Iridectomy was tried, but it resulted in phthisis bulbi.

Morax followed the plan of F. Reisinger, except that he attempted to transplant the leukomatous portion to the periphery, and the clear periphery to the center. Strauch, in 1840, preferred to dissect from one limbus to the other, using parallel blades, and Wolfe,[8] in 1873, finding the tissue opaque from lack of nutrition, made conjunctival flaps. Schaeler, in 1877, advised large grafts after complete resection of the leukoma, while Dürr and Rasenni,[9] in 1877, reported that only part need to be covered. Probably the thought of large flaps and better nutrition led to the transcorneal keratoplasty, which many men tried in modified forms. Among the most recent to devise and try this form of technic was Löhlein,[10] in 1910. His was essentially the idea of Wolfe in 1873, for his operation consists of a transcorneal section of required width across the cornea from limbus to limbus, making a generous conjunctival flap at each end. The thickness was controlled somewhat by the depth of the cut of the parallel blades. The flap was sutured in place at both sides by its conjunctival attachments, and the eye bandaged. His conclusions are that he has done forty of such grafts and is most satisfied with results, which are best, he thinks, following leukoma from burns, and most unfavorable after ulcer. He thinks that thin grafts are the best, but says that Thiersch grafts are hard to get.

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[8] Wolfe: Brit. Med. Jour., 1880, **2**, 780.

[9] Dürr and Rasenni: Klin. Monatsbl. f. Augenh., 1877, **15**, 305-311.

[10] Löhlein: Arch. f. Augenh., 1910, **154**, 179; Arch. Ophth. N. Y., 1912, **41**, 266.

Over a long period, therefore, many types and forms of operation were tried; and from them the larger questions arose, such as the type of tissue to be used, causes and prevention of opacity following operation, nutrition of the transplanted flap, and lastly the operative technic. We can therefore make these general deductions from the voluminous literature on this subject on the foregoing main points.

As is known, there are four different types of operation: autoplasty, homoplasty, heteroplasty and foreign body transplants. The latter can be at once dismissed, because of universal failure, and heteroplasty, which is at present a biologic problem. Bonnefon and Lacoste[11] stated that most failures were due to heteroplasty. Hence autoplasty and homoplasty are the two types to which most of the more recent experimenters have clung.

Autoplasty, as the name implies, is the transplantation of the cornea from one part of the eye to another part of the same eye, or from one eye to the other eye in the same animal. Homoplasty is the transplantation of corneal tissue from an individual of one species to another of the same species, or to a species not far removed. As the two types are similar, they will be dealt with together.

Among the causes of failures, other than those due to heteroplasty and foreign body transplants, has been the selection of cases. Healthy tissue should be the first prerequisite, although Fuchs asserted that he had had his best results in interstitial keratitis. Magitot doubted this. The depth of the leukoma should be taken into account. It should not extend to Descemet's membrane, for it has been shown by several men that it is necessary to get all of the leukoma and yet not puncture the anterior chamber. Magitot has stated that unless all the leukomatous tissue is obtained, the results will not be good, and no hope can be held out for a complete growth of the tissue. "The thing to know," he says, "is how deep the leukoma extends, but only at time of operation can this be determined." Leukomas as the result of ulcers, especially with posterior corneal synechiae, are not good operative risks. It is, of course, assumed that the conjunctival sac is free from infection, as this was the cause of most failures in the work of earlier operators.

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[11] Bonnefon and Lacoste: Compt. rend. Soc. de biol., 1912. Bonnefon: Arch. d'Ophth., Paris, 1913.

Of all the operative accidents, puncture of the anterior chamber appears as the leading cause of failure, although union has been obtained under these circumstances. Trauma of the graft while handling, loosening of a graft after transplantation by lid movements, and local necrosis from stitches were given by others as causes of failure.

As regards nutrition, there is a wide variance of opinion; for some authors hold that too much nutrition causes vascularization of the graft, and others take the opposite view. Salzer stated that the more vessels present, the more cloudiness and connective tissue. Zirm, on the other hand, tried to cover the periphery of the cornea with conjunctiva, to promote nutrition of the graft. Löhlein, in his later paper, stated that the best nutrition followed vascularization.

Hence, in summary of the foregoing notes of many different authors, it can be said that foreign body transplants and heteroplasty are bound to lead to failure, and that autoplasty and homoplasty offer the greatest chance of success. Still even in the latter two, the technic of operation and the selection of cases have a great bearing on the final result.

EXPERIMENTAL WORK

The technic of this operation was developed on the eyes of dead dogs, of which I had a plentiful supply from the physiologic laboratory of the University of Chicago. It was first found that it was impracticable to obtain the corneal grafts with conjunctival flaps attached, similar to those of Löhlein, from a dog, on account of the anatomic form of the socket and the third lid. The curvature of the cornea, even in man, makes it difficult to follow a surface of this kind, especially when a cataract knife is used. Hence some other method was necessary to obtain a large graft with sufficient nutrition. For this reason, the modified Thiersch graft was decided on, and the technic was developed to a fair degree after a great many trials on dead animals.

The live specimens were then prepared as follows: A mercuric chlorid bath was given, and the animals were isolated in fumigated cages. The eyes of the animals were treated for a period of three weeks previous to operation by 2 per cent. protargol instillation each evening, and washing out of the sac each morning with 1:4,000 mercuric chlorid solution. After smears showed the absence of the streptococcus and other virulent bacteria, the animal was ready for operation. The work was all done under ether, and with as much asepsis as a physiologic laboratory will permit.

Description of Operation.—The conjunctival flap is prepared thus: The bulbar conjunctiva is loosened up well over the whole area extending from 7 to 4 o'clock on the dial, care being taken to have it loose enough so that it can readily be pulled over the entire cornea without much tension. Some hemorrhage results, and the corneal graft is not removed until this has entirely stopped, as will be explained later on.

The eye is now prepared as in operation for cataract extraction, and after the conjunctiva has been grasped below with fixation forceps, a Graefe cataract knife is passed into the cornea at the required depth, and the point emerges on the other side as far as is possible or desired. Then by a sawing motion the flap is cut down as far as necessary, and the knife emerges, leaving the flap attached to the cornea at the upper pole. The flap is now grasped with the fixation forceps, and is gently lifted up and cut away at the upper pole. This yields a flap of corneal tissue about 3 by 5 or 4 by 6 mm. in size, which is somewhat irregular in outline, and of slight difference in thickness throughout.

The graft is now made ready for the host, by passing three or four fine silk ligatures through it at its corners and close to the periphery. On account of the difficulty encountered in this step, special forceps were designed which resemble standard fixation forceps with a notch cut in the middle third so as to allow the needle to be passed through the tissue in question.

The corneal cavity of the host is made in the same manner as described above and is larger in diameter than the flap. It is moistened with physiologic sodium chlorid solution, and the flap, immersed in the same solution, is laid on the eye. The sutures are inserted at the points at which the flap limits extend and just deep enough to hold, namely, about one-fourth to one-third the depth of the cornea. When all sutures have been inserted they are pulled taut, so as to approximate but not to strangulate the tissue. The thread is now cut off close, and the eye washed gently with physiologic sodium chlorid solution.

The flap is now carefully brought down over the entire cornea and sutured fast below with silk sutures. In dogs, the third lid is sutured over the flap and the flap and lids bandaged.

Forty-eight hours after the operation, the bandage is removed and the conjunctival flap loosened. One finds at this time some of the corneal sutures gone, and those that are not are taken away. Ethylmorphin hydrochlorid (dionin), 5 per cent. solution, along with weak mercuric chlorid irrigations are now used. On direct examination of the eye at this stage, one finds the corneal graft clouded and there is some injection. In fifteen days the process tends to clear, leaving some small blood vessels which after three to four weeks gradually disappear. The final result is a leukoma discernible under strong light. The outlines of the graft gradually disappear in from two to three months.

It has always been the aim to obtain a flap thinner than the tissue removed from the host, and one can see, after healing has taken place, the new tissue filling in the slight peripheral depressions in the cornea. After from three to four months there is little left to show how extensive the flap was, so smoothly is the corneal surface epithelialized.

Experimental Data.—The laboratory experiments on live animals consisted of operations on twelve dogs, part of which had both eyes operated on and part only one.

The operations on the first three dogs were entirely unsuccessful, for the anterior chamber was punctured and the eye sloughed out. The next three were partially successful in that in one dog the anterior chamber was punctured but the graft held. Organization and exudate filled in about the graft, forming a dense leukoma, and the animal was discarded. The other two were successful from the standpoint of technic, as the anterior chamber was not punctured and the flaps were held in place. After the first dressing one of the dogs managed to scratch his eye, and as a result the corneal flap sloughed out. The other dog retained his grafts, but a dense leukoma formed. In the foregoing six dogs, both autoplasty and homoplasty were tried.

Dogs 7 and 8 were operated on in the manner described and dressed on the third day. The grafts held, but there were slight depressions with some grayish material at the borders of the graft. On the sixth day both grafts were relatively clear, and injection was not so marked as before. The twelfth day showed beginning organization in both grafts, and on the twenty-fifth day there was marked organization and cloudiness. Subconjunctival injections of 8 mm. of sodium chlorid solution and two of 5 per cent. ethylmorphin hydrochlorid were given with no result. In six weeks the same condition was present, so the animals were discarded.

In Dog 9, autoplasty was attempted. Operation was performed as described. The final result was organization of the graft especially from the nasal side which foiled all attempts to correct. The dog had fair vision, as was evidenced by a good red reflex with the ophthalmoscope, only slight cloudiness, and ability to get about without much disturbance due to vision.

In Dogs 10, 11 and 12, profiting from previous work, we allowed the minimum amount of blood when the conjunctival flap was brought over the cornea. In all three dogs the grafts held well; some cloudiness was present on the fifth day which increased to the twelfth day and then gradually disappeared to the naked eye. The organization was less than in any previous group, and although it persisted for six weeks, under ethylmorphin hydrochlorid both it and the cloudiness gradually faded away. Ophthalmoscopic tests showed a normal red reflex, and focusing on the cornea revealed the graft, which could be discerned especially about its edges by its faint wavelike appearance. After four months the eyes in all three animals appeared normal to the naked eye, and the corneal surface was absolutely smooth and regular.

Case 1.—J. H., white man, aged 26, had dense leukomas covering the central third of the cornea in both eyes as the result of smallpox ulcers. Autoplasty was attempted on one eye only. The operation was performed successfully with exception that the leukoma was so deep that it was impossible to remove it all. When the conjunctival flap was loosened on the second day it appeared grayish and was attached only at its upper border. The attachment was so small that the flap was later brushed off by the upper lid. The final result has left the eye in a better condition as regards the leukoma than before operation. This demonstrates that corneal grafts heal poorly on diseased tissue, as has been shown by previous experimenters.

CASE 2.—T. J. S., white man, aged 23, had a slight opacity of central fourth of the corneal surface. Homoplasty was tried. A graft was taken from the eye about to be enucleated. The operation was performed successfully and at present the graft is in place with only slight cloudiness and organization, and appears to be gradually clearing up under atropin and ethylmorphin hydrochlorid.

CASE 3.—B. W., white woman, aged 19, had a slight opacity of one fourth of the cornea, the result of phlyctenular ulcer. Autoplasty was tried. The graft at present is in place, and cloudiness and organization are no more than would be expected at this time.

Data on the final result of the last two cases will be given later.

In my earlier experiments I allowed plenty of blood to remain on the surface of the cornea when the conjunctival flap was brought over, desiring to give the flap plenty of nutrition by this means. Invariably I found intensive cloudiness or organization, although healing had taken place readily enough. Later I reversed that procedure, and stopped all bleeding from the conjunctival flaps before bringing them down. This I find a much better method, for beside giving the corneal flap plenty of nutrition by means of the serum present, much less cloudiness and organization resulted.

Most of my earlier failures were due to sepsis and undeveloped technic, as punctures of the anterior chamber. Later, opacities and organization were due mostly to too much blood in contact with the flap, and the result therefore was not good.

CONCLUSIONS

1. Heteroplasty and foreign body transplants offer very small chance of success and should be discarded, according to the literature.

2. Autoplasty and homoplasty at the present time will terminate with fair results, depending on the technic of operation.

3. The modified Thiersch graft is a simple, satisfactory and expedient manner of obtaining graft.

4. The conjunctival flap, as described, offers sufficient nutrition with the minimum cloudiness and organization, besides serving to hold the graft in place while union is taking place.

5. With properly selected cases, this operation will give good results.

[Live specimens will be shown.]

25 East Washington Street.

MEMORANDA

MEMORANDA

TENDON SHORTENING

AUTHOR'S METHOD *

H. H. BRIGGS, A.M., M.D.
ASHEVILLE, N. C.

Convergence is the most interesting function of the human eyes save the visual act itself. In the process of evolution it is the last oculomotor function to develop, reaching its highest degree in monkeys, apes and man. But convergence is a means to an end. It is a motor function necessary to the higher and more intricate sensory function of binocular vision, which in man is a still higher instance of evolution. A wonderful function it is when we realize that before fusion is possible, normally constituted eyes must receive from every object two sets of sensations which must be blended into one through the fusion center by carefully coordinated ocular movements so fixing the eyes that images may fall on corresponding retinal areas. In order to obtain binocular vision, certain mechanical conditions are necessary, the fulfilment of which requires a function of wonderful accuracy. With eyes of normal acuteness of vision, a deviation of the visual axis of $\frac{1}{50}$ degree means an error in the relative length of opposing muscles of only $\frac{1}{230}$ mm., being $\frac{1}{6000}$ inch, or one-half the diameter of a red blood corpuscle.[1] How futile it is, then, to expect, from mechanical readjustment alone, the fulfilment of conditions rendering binocular vision possible. Let us not forget the importance of fusion and its stimulus in this question of muscle readjustment and binocular vision. The treatment of strabismus is a matter of neuromuscular dynamics, and the question should always be, How will the proposed readjustment influ-

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* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June, 1917. Publication rights reserved by the American Medical Association.

[1] Jackson, Edward: Principles Controlling Operative Interference in Strabismus, The Journal A. M. A., Nov. 1, 1902, p. 1105.

ence the innervation of the muscle? An operation should aim at as exact adjustment of the visual axes as possible, considering the age of the patient, the muscle and tissues to be operated on, the refraction and accommodative effort, the probable amount of cicatricial changes with healing and with increasing age, and in a certain class of strabismus, the fact that the eyes have not hitherto participated in binocular function.

PRECISION

No operation requires greater precision than that for readjustment of ocular muscles. We appreciate this the more if we remember that for each millimeter a muscle is shortened or lengthened, from 3 to 5 degrees of rotation is affected, and that 1 degree of deviation, if uncorrected, means diplopia for small objects. To illustrate: A letter in the $^{20}/_{200}$ line of the test card subtends an angle of 50 minutes of an arc, the width of the bar composing the letter subtending an angle of 10 minutes or $1/_6$ degree, so that if there should be an uncorrected deviation of one eye upward, say of 1 degree, which could not be corrected by the stimulus of fusion, the person would see two letters, one above the other, with a space between them equal to the width of one of the bars making the letter. Such diplopia would be disturbing indeed, and an error of 0.2 mm. in readjusting the eye would produce this diplopia, were it not fortunately that physiologic stimulus of fusion comes to our rescue and corrects such small errors.

In certain methods of advancement, especially those involving section of the tendon, it is difficult to determine within 3 mm. the exact point of final reattachment of the tendon, and this possible error of 3 mm. means from three to five times this amount, or from 9 to 15 degrees of uncorrected phoria or tropia. Is it surprising, then, that our ultimate effect is often far from what was intended? It is consoling, however, to know that for every 5 degrees of phoria or tropia which we have failed to correct, it has meant a failure of perhaps only 1 mm. of adjustment. The readjustment, therefore, not only at the time of operation, but also after final healing, should be within 1 mm. of the calculations in keeping with muscle balance.

VARIOUS METHODS

More than sixty methods of increasing the power of an ocular muscle may be found in the literature. These may be divided into three classes: (1) those in which the tendon is severed and a new insertion made nearer the cornea; (2) those in which the insertion is not severed but the muscle shortened by tucking or resection, and (3) those in which the tendon is tucked or folded and the overlapped portion attached anterior to the insertion.

AUTHOR'S METHOD

Since 1909 I have used almost exclusively the following method of tendon shortening without severing the tendon and without the use of needle and suture:[2]

The method is applicable to any case in which shortening of an ocular muscle is indicated. The principle involved is the looping of the tendon and maintaining the shortening thus attained by means of a silver link (Fig. 1 *A*) clamped over the loop and retained there until inflammatory adhesion takes place between the advanced portion of tendon and the sclera. The link, which is elliptic, is made of silver wire (No. 20, Brown and Sharpe Standard). It is long enough to extend across the tendon, and wide enough to allow a small tendon hook with the looped tendon and overlying conjunctiva to pass through its lumen. The major axis of the link should be about 5 mm., the minor about 2 mm. Pure silver wire gives the proper amount of resiliency, retains its compressed shape, is easily removed, and seems to serve better than an alloy. To insure against the tendon retracting through the link, burrs may be punched on the inner surface of the link to act as barbs against the pulling action of the tendon.

A clamp forceps (Fig. 1 *B*) is used to grasp the silver link in its jaws and hold it in position over the tendon until the loop of tendon and conjunctiva is drawn up through the link, when by compressing the forceps the link is compressed sufficiently firm over the loop to maintain the loop the required time after the forceps have released the link and left it in situ. Passing entirely across the approximating surface of the jaws near the tips are transverse grooves deep enought to hold the long parallel sides of the silver link. The length of jaw to the angle is sufficient to accommodate the longest loop of tendon that may be desired. A ratchet maintains the jaws in any compressed position over the link.

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[2] Briggs, H. H.: Tr. Sect. on Ophth., A. M. A., 1909.

A special tendon hook (Fig. 1 *C*) is used, differing from the ordinary small tenotomy hook in that its shank, 6 mm. above its angle, is bent backward in the plane of the hook at an angle of about 15 degrees. This bend allows the handle of the tendon hook to be held out of the operator's line of vision, and at the same time the hook may remain parallel to the tangent plane of the eye at the site of operation. The hook should be short enough to pass through the major axis of the link, and yet sufficiently long and strong to pull the tendon through the link, overcoming the pull of the opponent muscle, which may or may not have been previously tenotomized.

For removal of the link, scissors forceps with wedge-shaped blade above and flat blade below (Fig. 1 *D*) are used to divide each end, when the severed halves of the link may be removed with small tissue forceps.

After the usual preparation of sterilization and anesthetization, the operator, standing on the side of the eye nearest the muscle to be shortened, makes a small opening in the conjunctiva on one side (the operator's right side) of the tendon near its insertion into the sclera, the distance from the insertion varying with the degree of advancement intended. An ordinary tenotomy hook passed beneath the tendon is held by an assistant, the clamp forceps holding the silver link is held over the tendon with one hand, and the special tendon hook passed down through the silver link is substituted for the hook held by the assistant. The tendon with its overlying conjunctiva is drawn up through the link to the desired degree, and the jaws of the clamp forceps forcibly approximated. If the degree of deviation is great, and the tendon loop to be made long, the conjunctiva may be incised, allowing the tendon only to be advanced to any desired degree. It may be necessary in excessive advancements to excise the greater part of tendon and tissues protruding through the link, leaving only enough to insure nonretraction of the tendon ends through the link.

The moderate edema of the tissues about the link immediately covers it so that no irritation is felt from the presence of the forèign body. Within twenty-four hours the strangulated tissues become white and begin to atrophy, and on removal of the loop, in from ten to fourteen days, they should be excised.

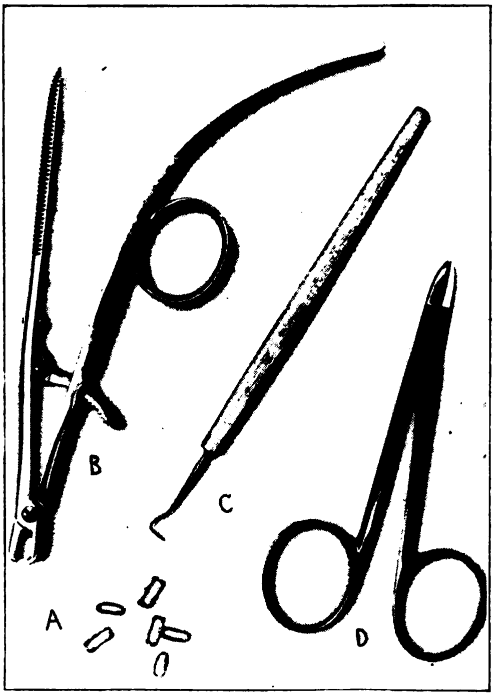

Fig. 1.—Instruments employed: *A*, silver link; *B*, clamp forceps; *C*, tendon hook; *D*, scissors forceps.

The advantages of this operation over the usual methods of advancement are:

1. Simplicity.
2. Elimination of needles and sutures.
3. Avoidance of tenotomy of the advanced muscle.
4. Absolute security from slipping or retraction of tendon.
5. Short duration of time of operation.
6. Less pain.
7. Less amount of plastic inflammation during convalescence.
8. Short period of convalescence.
9. Less scar and deformity.

Since the operation was devised in 1909, I have operated in 131 cases of phorias and tropias with satisfactory success generally, the only exceptions being in three cases, in which the link failed to hold. In the first case, the patient returned to the office on the day following operation, when the link could not be found either in the conjunctival sac or in the dressings. Whether it was not sufficiently compressed and slipped off the loop of tendon could not be determined. The muscle was again immediately operated on, and the usual good result followed.

Failure in the second case was due to imperfection of the link; it had been broken at one end, and, becoming loosened, was found in the conjunctival sac the following day.

Failure in the third case was due to the grooves in the jaws of the clamp forceps being made too shallow, allowing the link to slip out of their grasp. This operation was done in a demonstration clinic at the Southern Medical Association meeting in Atlanta last November, the imperfect instrument being borrowed from an exhibit for the occasion. The link came off a few minutes after the operation was concluded. In no other case has there been any slipping of the loop of tendon representing the shortening.

In no case has the advanced portion of tendon failed to unite with the sclera, at and immediately back of the original insertion of the tendon. This was found to be true in cases in which second advancements on the same muscle were found necessary—the tendon hook encountered no adhesion far back of the original insertion, as is usually the case after other methods of advancement. In no case has a vertical deviation resulted from operation on a lateral muscle, as sometimes happens when sutures are used and the anchorage on one side gives way.

Many patients prefer to have the eye unbandaged, and most patients complain of no more pain or discomfort than after tenotomy. One patient, a boy of 12, with intermittent exotropia, played baseball with eyes unbandaged the same afternoon and on each following day without seeming inconvenience.

Removing the link is the most difficult part of the operation — difficult principally because the link-cutting forceps are often not made accurately. The upper cutting jaw should be so shaped that it meets the lower jaw most firmly at the extreme tip, and it must be kept sharp; otherwise it will not cut completely through and sever the link.

Often failure in advancement operations is due to the character of tissues dealt with. The conjunctiva and subconjunctival tissues are extremely elastic and easily dragged away from their normal position. They may be cut through with sutures at the time of the operation, or later, by softening or sloughing, they become an unreliable anchorage, and militate against an accurate result.

The presence of sutures may induce infection, which in turn may add to the softening and insecurity.

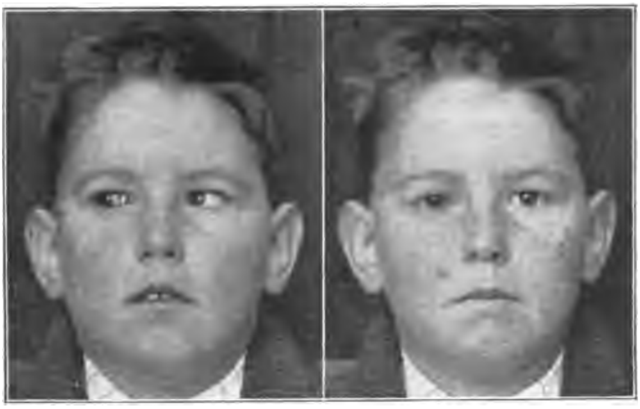

Fig. 2.—Condition of the eyes in patient one day after operation.

The placing of sutures in itself is a somewhat dangerous procedure.

Howe[3] says, "One of the greatest difficulties in all these operations is that they require the anchorage to be made in what is usually described as the 'episcleral tissue'; but in reality the sutures are seldom or never in the episcleral tissue only. They are either in the conjunctiva, which is elastic and easily torn, or the needle enters the sclerotic itself," which, being but 1 mm. thick, is often punctured and the ciliary region invaded. He mentions a colleague who broke a small needle, the point remaining in the ciliary region and being extracted only after a careful and long search.

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[3] Howe: Muscles of the Eye, 2, 350.

Worth[4] says:

> Sutures must have a firm hold in the sclerotic; no other mode of attachment can be depended on. My sutures traverse two thirds of the thickness of the sclerotic. This exact depth which I have used for many years without accident is certainly safe, but if a suture were inserted through the whole thickness of the sclerotic it would probably lead to loss of the eye, and I have heard of such catastrophe.

Apropos of this statement is the following from Howe:[5]

"The layer of scleral tissue near the cornea is only about 1 mm. thick. The smallest needles measure from 0.6 to 0.8 mm. A larger needle either does not penetrate the sclerotic, or if it does it is at the risk of passing through into the ciliary region." How difficult, then, it must be to pass a needle "exactly two-thirds" [4] through a membrane 1 mm. thick.

Woodruff[6] has seen two cases of perforation of the sclera, one of sloughing of the sclerotic and two in which the caruncle was drawn toward the cornea.

Wirts[7] reports a case of phthisis bulbi, following an advancement operation.

Cowgill[8] mentions an ulcer of the cornea in which there was no injury of the cornea at operation. The eye was preserved, but a leukoma extending to the center of the cornea resulted. He attributed the ulcer to the reduced nutrition from the severing of the conjunctiva and the pressure of the anchoring sutures.

Webster[9] stated that he had seen one eye lost of panophthalmitis, three or more cases of ulcer of the cornea, and in more than one case the operator's needle had penetrated the anterior chamber.

Noyes[10] saw needle points enter the anterior chamber.

Cogan, in operating on pigs' eyes, found he had perforated the sclera in half of them.

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[4] Worth: Claud: The Operation of Advancement of a Rectus Muscle, Ann. Ophth., 1902, **11**, 377.

[5] Howe: Muscles of the Eye, **2**, 351.

[6] Woodruff, H. W.: Shortening of an Ocular Muscle by Tucking, THE JOURNAL A. M. A., Aug. 5, 1911, p. 461.

[7] Wirts: Ztschr. f. Augenh., January, 1910.

[8] Cowgill: Ophth. Rec., **10**, 3.

[9] Webster, David: Tr. Am. Ophth. Soc., 1908, **2**, 3.

[10] Noyes, H. D.: Textbook, Diseases of the Eye, p. 172.

Zentmayer[11] has seen the needle enter the anterior chamber on two occasions, and he once had a perforation of the sclera and loss of vitreous from sloughing.

Woodruff[6] states that the reason serious accidents do not follow advancement operations oftener is that the operator, erring on the side of safety, prefers insufficient anchorage to perforating the sclera, and leaves us to infer that in operations of true advancement in which attempts are made of anchoring in the so-called episcleral tissue, the eye is endangered, on the one hand, or an insecure anchorage results, on the other.

Landolt,[12] who said that "the dosage of tenotomy is uncertain and from the dynamic standpoint its effects are unfavorable," might have added that the effect of advancements, as usually performed, is also, though to a less degree, uncertain.

While the conjunctival sac and the lacrimal secretions have certain bactericidal properties, wounds of the eye are prone to infection, and especially is this true when any foreign substance, such as silk or catgut, remains in the eye. The substance best tolerated in any part of the body, and especially by mucous membrane, is silver, which in the form of a small link is the only substance used in the author's method, and it is so placed that it does not even penetrate the tissues.

Some operators believe that by advancing a muscle above or below the original attachment a coexisting hyperphoria may, with the lateral deviation, be simultaneously corrected. It may be argued that the author's method (the same would apply to all tucking methods), leaving the insertion intact, precludes the possibility of effecting this dual result. While this is true, the operator is more than compensated for this lack by the assurance that by not severing the tendon and keeping the advanced edges in absolute juxtaposition, assured by the shape and length of the silver link, he not only cannot correct a deviation in the vertical meridian, in case of hyperphoria, but furthermore, he *cannot* produce a hyperphoria by miscalculation or by accidentally misplacing the tendon vertically in cases in which no vertical deviation exists, as often happens to the best operators after severing a tendon and attempting to advance it along the horizontal meridian.

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[11] Zentmayer, William: Changes Occurring in the Refraction of Corrected Ametropic Eyes, The Journal A. M. A., Aug. 5, 1911, p. 470.

[12] Landolt in deSchweinitz: Diseases of the Eye, p. 552.

The author's method also assures against the accidental production of cyclophoria. In an editorial, "Muscle Shortening versus Muscle Advancement," Savage[13] warns against the danger in advancements of accidentally turning the eyeball on its anteroposterior axis so as to throw unbearable strain on the obliques.

Leaving the tendon intact, aside from lessening trauma, insures, therefore, against induced hyperphoria, induced cyclophoria, and against the severed muscle retracting and producing a much worse squint than was first attempted to correct.

It may be said that the author's method does not allow the operator to watch the effect produced during the operation, and modify the tension of the sutures to meet the indication, as is done in the Prince and other methods of the pulley type. Concerning this, Jackson[14] says:

> This ought not be depended on to the neglect of careful calculation beforehand of the exact effect to be aimed at. Only when some unfortunate factor intervenes and the effect produced proves quite different from that expected is it wise to modify a carefully proposed plan of operation. Under the stress of operation with local anesthesia, the patient's answers as to the subjective tests become especially unreliable.

In the author's method the only trauma to the eye consists in making the smallest possible incision through the conjunctiva and subconjunctival tissues, barely large enough to admit a tendon hook to be passed underneath the tendon. The only manipulation otherwise is the traction of the hook on the tendon and conjunctiva in bringing them through the link. The entire traumatized area, including the incision, is drawn through the link and ultimately excised. Thus there not only is no suture in the tissues, but also the only foreign body present is one of silver, which clamps the tissues together rather than penetrates them. There is less trauma than in any other operation done on the ocular muscle.

The time required will average about two minutes, and the amount of pain and discomfort is practically nil; far less than in any method of tenotomy.

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[13] Savage: Ophthamologic Myology, Ophth. Rec., 1893, 2, No. 9.

[14] Jackson, Edward, in Wood: System of Ophthalmic Operations, 6, 749.

MEMORANDA

MEMORANDA

TENDON TRANSPLANTATION OF THE EYE MUSCLES *

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By tendon transplantation is understood the transference of all or a part of a tendon from its normal insertion to a new one, in such a way that its physiologic function will be changed. The object to be gained by such an operation is not so much the restoration of function in a paralyzed muscle as the substitution of a normal one in its place.

Little in this particular field has been done in ophthalmology. Most cases of incurable muscle paralysis are dismissed as beyond surgical relief, or the operation of advancement of the paralyzed muscle with tenotomy of the contracting opponent is advised. In this way, in incomplete paralysis, good results may be obtained without doubt; but in complete paralysis of a single eye muscle I have never secured a satisfactory result by advancement with tenotomy. I have been a consistent follower of such writers as DeWecker,[1] Landolt[2] and Prince,[3] and I have no doubt that at present their operations, or similar ones, are followed by the majority of eye surgeons when time and treatment have determined that a paralysis is incurable. Dr. Jackson of Denver is the only American writer I know of who has suggested any radical departure from these methods, and it is due to his various references, notably one before this section in 1908, that I was induced to try tendon transplantation in two cases of abducens paralysis which recently came under my care.

Tendon transplantation has yielded results in general surgery. May it not have a future in ophthalmic sur-

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* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June, 1917. Publication rights reserved by the American Medical Association.

[1] DeWecker: Arch. d'ophth., 1904, **24**, 421.

[2] Landolt: In Norris and Oliver's System, **4**, 66.

[3] Prince: Am. Jour. Ophth., **19**, 259.

gery? As early as 1770, Missa[4] restored function to a finger by substituting other tendons to an extensor which had been severed and could not be sutured. Velpeau[5] advocated this method in 1839.

In 1881, Nicoladoni,[6] at the annual meeting of the Society of German Naturalists and Physicians, showed before the surgical section a 16 year old boy whom he had recently operated on for paralytic talipes calcaneus. As all the calf muscles were paralyzed, the tendons of the two peroneal muscles were divided and the central ends were implanted into a longitudinal slit in the Achilles tendon. He showed the members of the society that the contraction of the peroneal muscles produced plantar flexion of the foot, while the patient's gait was considerably improved. This brilliant result was unfortunately not permanent. The suture pulled out and the final result was nil. At about this time four or five others tried the operation with negative results, and it was given up by German and Austrian surgeons as early as 1886.

The first American surgeon to do the operation was Parrish[7] of New York, who in 1892 transplanted tendons in a case of clubfoot.

At present, tendon transplantation seems to occupy a place in the surgery of paralysis, although writers differ as to methods and results. Ryerson[8] of Chicago says:

> The two principal methods to be considered are those advocated, respectively, by Vulpius of Heidelberg and by Lange of Munich.
>
> In the Vulpius method, the entire healthy tendon, or a portion of it which has been partially split off from it, is sutured to the tendon or muscle which it is intended to strengthen. This method and its modifications have been so extensively used by Vulpius and his followers that there would seem to be little doubt of its efficacy. In my experience, however, it has been found of value in only a limited field. It is useful, particularly in the arm and forearm, and in supplying power to the flexors and extensors of the toes; but when used where a considerable strain is to be thrown on it, as in the tibial or peroneal muscles, it shows a tendency to lose its efficiency. This may be due to the stretching of

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[4] Missa: Gaz. Salut., 1770, No. 21.

[5] Velpeau: Operative Surgery, 1839.

[6] Nicoladoni, cited by Waterman, J. H.: Med. News, July 12, 1902.

[7] Parrish, in Da Costa: Surgery, 1908.

[8] Ryerson, E. W.: The Surgery of Infantile Paralysis, The Journal A. M. A., Nov. 1, 1913, p. 1614.

the paralyzed tendon, but in many cases cannot be referred to any definite cause. The operation is technically easier than the method of Lange, but it is not so certain in its results.

After a considerable experience with the method of Vulpius, I began, some years ago, to use the periosteal implantation of Lange. This gave satisfaction in many of the cases in which tendons were transplanted, but proved not strong enough for the silk suspension cords or ligaments used in cases of dropfoot.

The principle argument, then, seems to be over the method of implantation or attachment, and I will here quote from Mayer[9] of New York, to whose writings any one interested is referred. Mayer says:

> A rational system of tendon transplantation must be based on an accurate knowledge of the anatomy and physiology of tendons and muscles. That our present systems are empiric rather than rational is shown by the marked discrepancy in the operative methods of prominent orthopedic surgeons. Thus Lange, on a basis of over 2,000 tendon operations, is radically opposed to Vulpius, whose experience is almost as great. Lange insists in the periosteal implantations of the tendon, and lengthens the tendon artificially by silk strands. Vulpius maintains the advantages of sewing the transplanted tendon to the paralyzed tendon as advocated by Nicoladoni in 1882.

In the same article Mayer says the principle cause of failure in addition to inefficiency of fixation is postoperative adhesions on account of disturbed relationship between the tendon and its sheath.

In the eye muscles, Parinaud[10] and Motais[11] were the first to utilize a part of one muscle to perform the work of another. The Motais operation has now become a rather popular method for the cure of ptosis.

Edward Jackson[12] has operated for paralysis of the superior oblique by transplanting the superior rectus to a new insertion farther backward and outward from its normal insertion, thus relieving the tendency of the eye to turn upward, and at the same time increasing the power of intorsion and abduction.

Hummelsheim,[13] in 1907, performed several experimental operations on two monkeys by transplanting the nasal halves of the tendons of the superior and inferior recti to the attachment of the internal rectus after destroying its action by an extensive resection of its tendon. In the first animal there was no noticeable disturbance of motility after six weeks. The second animal died from some unknown cause, before any observation could be made.

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[9] Mayer: Surg., Gynec. and Obst., February, 1916, p. 182.

[10] Parinaud: Ann. d'ocul., 1897, **117**, 12.

[11] Motais: Bull. et mém. Soc. d'ophth. de Paris, 1898.

[12] Jackson, Edward: Ophth. Rev., 1903, p. 61.

[13] Hummelsheim: Ber. d. ophth. Geselsch., Heidelberg, 1907, p. 248.

Hummelsheim refers to a work of Marina in which he discusses the transplantation of the superior oblique for the removed internus or externus. Marina referred to Dr. Cofler as the operator, and said that he would report concerning the technic and the practical results in man. Hummelsheim, however, was not able to find any such report. His own experimental operation and the statements of Marina, were sufficient to cause him to attempt the operation on the human eye.

A 12 year old girl came to him with presumable congenital paralysis of the right abducens. The eye could not be turned outward beyond the median line. He transplanted the temporal halves of the superior and inferior recti and obtained an abduction of 30 degrees without any loss of vertical rotations. Binocular vision, however, was not obtained.

Hummelsheim[14] reports a second case one year later. This patient was a woman, aged 47, with an incurable acquired paralysis of the abducens, of eight months' duration. He performed the same operation with somewhat different technic and without tenotomy of the internus, stating that he did not wish to alter the scope of the operation experiment. The result of the operation was parallelism when the eyes were looking straight forward. Double vision was abolished except on extreme abduction. In this case there was some limitation of the upward rotation, but fortunately not in rotation downward. As this paralysis did not appear until five months after the operation, he argues that it was not traumatic, that is, caused by his operation.

Stuelp,[15] Jan. 6, 1912, operated after the same method in a case of marked convergent paralytic strabismus. On the third day he noted that there was a marked improvement in the strabismus but no further active outward movement of the eye. This later was effected after three weeks more following a tenotomy of the rectus internus. Stuelp states that his result was functionally not brilliant but that the condition was improved.

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[14] Hummelsheim: Arch. f. Augenh., 1908, **62**.

[15] Stuelp: Klin. Monatschr. f. Augenh., 1912, **50**, 467.

REPORT OF CASES

CASE 1.—*History.*—Nov. 14, 1916, Dr. Charles Burkholder of Chicago referred to me a case of paralytic convergence in a girl, aged 20 years. She attributed her paralysis to a fall, when 6 years of age, in which she struck on the head behind the left ear. When 15 years of age she had had an advancement of the paralyzed muscle with tenotomy of the internus. This, she thinks, had improved her condition to some degree. About a month before Dr. Burkholder saw her she had had another tenotomy of the internus.

At the time of her admission to the hospital, she had 20 degrees of convergent strabismus when looking straight forward, but only the slightest perceptible movement of outward rotation (Fig. 1).

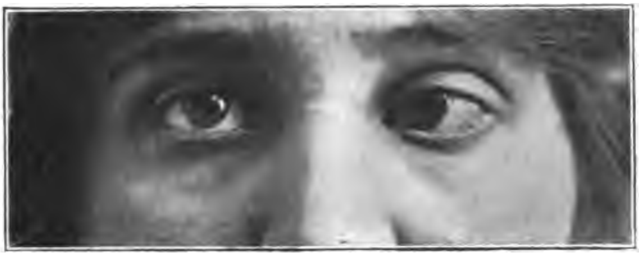

Fig. 1.—Case 1: Paralysis of the left external rectus; fourteen years' duration.

Realizing the hopelessness of the ordinary procedures and the repeated failures, I considered the advisability of transplanting the whole of the tendons of the superior and inferior rectus muscles to two points on the globe midway between the superior rectus and the externus, and between the inferior rectus and the externus, respectively. After reading of Hummelsheim's experiments and results in his two cases and the fact that the function of the superior and inferior rectus were not disturbed, I followed his method.

Operation.—Anesthesia was secured by subconjunctival injections of novocain and epinephrin over the sites of the four rectus muscles. The tendons of all four muscles were exposed by incisions through the conjunctiva and capsule. The outer halves of the tendons of the superior and inferior recti were separated for about 12 mm., and each tendon flap was sutured to the tendon insertion of the paralyzed muscle with 00 catgut treated with formaldehyd (Fig. 2). The internal rectus was freely tenotomized and the conjunctival wounds closed with silk. Both eyes were bandaged for three days. The operated eye was bandaged for one week. Figure 3 shows the results two weeks afterward. There was distinct improvement but still a slight convergence. This I attempted to relieve by shifting the remaining normally attached portion of the superior and inferior recti to positions slightly outward so that they would no longer act adductors. This secondary operation was of doubtful success, so that at present the condition is substantially as in Figure 3, two weeks after the first operation.

Case 2.—Dec. 26, 1916, I performed the same operation on a boy, aged 7 years. He had been brought to me the previous May with a marked internal paralytic squint of the left eye (Fig. 4). When he was 7 months old, the left side of his face was paralyzed, and the eye turned in at the time. He had had an operation of advancement and tenotomy four years before without result. It was suggested to the parents of the patient that there was a possibility of straightening the eye, which was finally attempted, Dec. 26, 1916, with the result shown in Figure 5.

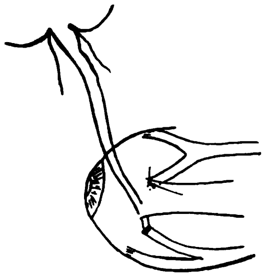

Fig. 2.—Method used by the author in performing partial tendon transplantation.

The operation was the same as that in the first case. The result, however, cosmetically was better, but functionally the same, as there was no movement outward beyond the median line in either case. As both these patients were amblyopic in the paralyzed eye, the question of diplopia did not arise.

It will be noticed that in Hummelsheim's experiment on the monkey, he reports no loss of motility after six weeks.

Partial paralysis produced by operative interference is not exactly comparable to complete paralysis from central causes.

In his case of the 12 year old girl there was ability to turn the eye outward to the median plane; therefore the paralysis was not complete. The securing of 30

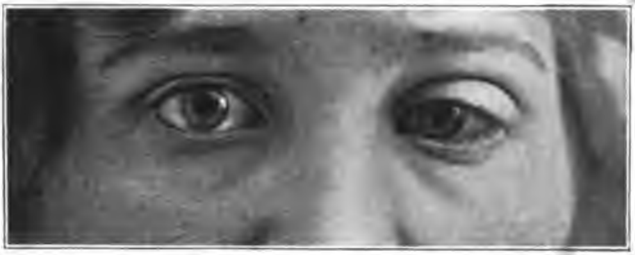

Fig. 3.—Case 1: Result after partial tendon transplantation of the superior and inferior recti muscles to the external rectus.

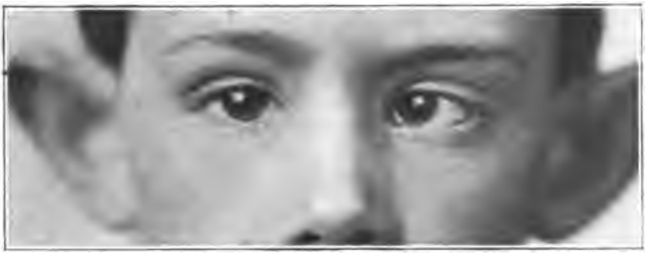

Fig. 4.—Case 2: Paralysis of the left external rectus, six and one-half years' duration.

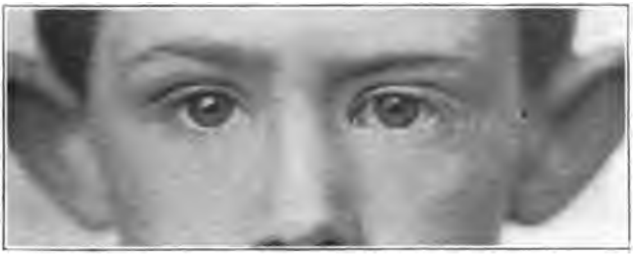

Fig. 5.—Case 2: Result after partial tendon transplantation of the superior and inferior recti muscles to the external rectus.

degress of abduction was a brilliant result, yet the patient undoubtedly possessed horizontal rotation of that amount before the operation.

In the case of the woman aged 47, he does not state the degree of rotation; but the result was good, as he secured parallelism when the eyes were directed straight forward, and double vision abolished except on extreme abduction.

Stuelp himself claims an improvement only in the strabismus in his case; and my two cases would also tend to show that while restoration of function is not possible to any degree by partial transplantation, improvement in the strabismus is possible. The failure to secure altered function that is abduction in these two cases is probably due, as Mayer states, to adhesions, so that the superior and inferior recti do not act from the new point of insertion, but at the point at which the tendons were split, the transplanted tendon flaps acting more as ligaments to hold the eye outward, especial after the tenotomy of the internus.

Nevertheless, it would seem that the results in these five cases (omitting the animal experimentation of Hummelsheim) should place incurable paralysis in the operative class.

Whether or not work along these lines will lead to improvement in function, the static result is certainly worth while.

MEMORANDA

MEMORANDA

LYMPHATIC-NODULAR KERATOCONJUNCTIVITIS (PHLYCTENULES) *

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Phlyctenular keratoconjunctivitis has always impressed me as a distinct ocular evidence of a systemic dyscrasia; in other words, these nodular exudates indicate a weakened, anemic constitution. The impoverished patient requires more than general tonics, something more definite and specific in the line of treatment. As an increased heart beat would be suggestive of some abnormality, so I take this eye condition to be a symptom of some abnormal constitutional condition. As interstitial keratitis is a manifestation of inherited syphilis, these nodular lymphoid infiltrates are evidences of a strumous diathesis or tuberculosis — if not tuberculosis, then something very similar, bearing in its symptomatology a striking resemblance to tuberculosis. These nodular exudates are warnings, and not outspoken evidences of tuberculosis. The absolute certainty, as clinical evidence of it, must remain unanswered for the present. The proof is not sufficient to warrant such an assertion, yet in the large percentage of these cases it distinctly gives evidence of an intimate association with tuberculosis. We all know of tuberculous cases undergoing spontaneous arrest, and these may be some of the cases that give symptoms accompanying tuberculosis but not made manifest by our present methods of examination. Of course further evidence must be forthcoming, but I believe a proper interpretation of this local sign will be a great aid to us in saving and restoring vision.

Since the vision which has been lost depends so much on the location of the resulting corneal opacity, it is not possible to generalize in regard to it.

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It is by a thorough and complete physical examination of all cases showing these nodular lymphoid deposits on the corneascleral border, especially when ulcerating, that we can get some evidence of tuberculosis in one of its many manifestations. In some of the thirty-nine cases which form the basis of this study we have distinct and clear evidence of tuberculosis.

I would not style the nodules tuberculous simply because giant cells are seen in some of their sections. If organisms are found they are a secondary infection, due to the lymphoid cellular exudates breaking down. This nodular cellular infiltrate is a manifestation of a disease and not the cause of disease. There is an underphysical tone, a latent tuberculosis, that causes nodular infiltrates to appear on the corneoscleral border. To me it is an exhibition of a tuberculous condition or one very closely allied to tuberculosis — call it scrofula.

In seven of the thirty-nine cases, pulmonary tuberculosis was found. I hold that when tuberculosis is fully established we shall not find this eye condition. These nodular exudates are seen only in a beginning tuberculous infection and not when tuberculosis is fully established. It is more of a manifestation of tuberculosis, especially in childhood, though we saw these cellular infiltrates in four cases in adult life.

In sixteen cases we found some form of tuberculosis. Fourteen of the patients had tuberculous adenitis. One of the sixteen had tuberculous wrist joint; one had a tuberculous hip.

Eight of the patients, while not having positive pulmonary signs, had suggestive lung involvement, as apical moist râles, impaired notes, dull percussion, and spotty infiltrates. One had an indurative mediastinitis. Three, from roentgenographic reports, showed upper apical infiltration. One had tuberculous arthritis.

Thirty-two of the patients had positive von Pirquet reactions; fifteen of them +, ten + +, four + + +, and two had a slight positive reaction.

Dr. J. H. Elliott[1] of Toronto says, "It has been our experience that every child that has phlyctenular conjunctivitis has given a tubercular reaction."

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[1] Elliott, J. H.: Tr. Natl. Assn., Study and Prev. Tuberc., 1916, p. 45.

In four of the cases the tubercle bacillus was found in the sputum. Three of the patients were sent to the state sanatorium for tuberculosis.

Eighteen of the patients had adenoids and diseased tonsils. The interesting point about these cases was the fact that in microscopic sections the tubercle bacillus was found in six cases.

The eczema seen in these cases is caused by the profuse lacrimation, and the constant epiphora is the irritant to the skin and nares. Nasal obstruction aids the eczema and the excoriation of the skin surfaces. Improper nasal respiration in the upper air passages, caused by congestion and intumescent turbinals, prevents the proper flow of tears to the nasal cavity. The mucous membrane of the tear duct and its sac becomes swollen and the lumen is narrowed, so that the tears do not have proper drainage to the nose. The eczema is a secondary factor, an association and not a cause of the eye condition.

Thirteen of the patients had a negative Wassermann reaction. Two had positive reactions; one of the latter patients, aged 20, had a nodular exudate on the conjunctiva with slight photophobia, lacrimation and a negative von Pirquet reaction. Roentgenoscopy revealed infiltration beneath both clavicles. Because of the negative signs of a tuberculous involvement, and of a positive Wassermann reaction, the patient was placed on antisyphilitic treatment. The condition of the second patient, aged 25, was similar to that of the first, and the same treatment was given.

In seven of the cases some member of the family had tuberculosis, four in parents (three paternal and one maternal), two in sisters, and one in a paternal uncle.

The age of these thirty-nine cases varied from 1 year to 30. There were thirty females and nine males. Eighteen patients were white and twenty-one colored. The cornea and conjunctiva were involved in thirty cases. Corneal ulceration was present in eighteen. The conjunctiva was involved in nine cases. Both eyes were involved in twenty-one cases, the right eye twenty-nine times and the left eye eleven times.

When local treatment was required for corneal ulceration we used atropin in 1 per cent. solution and protective glasses. When there was no corneal ulceration, sodium borate drops were ordered.

I have carefully gone over the cases and itemized each particular case for study: After the eye was seen and diagnosis made, the patient was referred to the Phipps Clinic for Tuberculosis for a physical examination and a skin test. It is needless for me to say that the work in that department is so thorough that the diagnosis will not be questioned. In fact, when one is working on a special subject, sometimes the enthusiasm gets the better of discretion, and one is liable to err. The reference of these cases to another department is bound to result in more accurate reports, and the results in the long run will be more valuable.

With their varied experience, the physicians in this clinic are unusually competent to make physical examinations and are especially skilled in giving the tuberculin injections. The dosage, temperature, pulse and respiration are followed more accurately. It is important to know how to administer tuberculin. It is a dangerous drug; and unless used skilfully, more harm than good will come from its administration. The minimum dose was 0.000001 gm.; to the small dose often repeated I think is due the success in giving tuberculin. The tuberculin used was the bouillon filtrate and was made in the Phipps Clinic for Tuberculosis. I feel confident that had it not been for their skilled and expert administrations of tuberculin, the results would not have been what they are. Unless the ophthalmologist has had experience in this line of work, it is better to have the work done by men who are doing that kind of work every day; they are more capable of judging the proper dosage, and the interval in time.

At least forty injections are necessary in an average case, and prolonged tuberculin injections a necessity for good results. Any rise in temperature is an indication of too large an amount of tuberculin, and with any redness or soreness at the point of injection, the dose should be diminished. Small doses often repeated constitute the treatment; this is so important that I wish to lay special emphasis on it.

In some of the thirty-nine cases we had a positive von Pirquet reaction, but the physical examination showed "no active pulmonary signs"; nevertheless, we tried tuberculin to see if it improved the ocular condition. We were surprised in seeing the nodular exudate disappear. To satisfy the patient, sodium borate drops were ordered. This improvement in the patient I attribute to the tuberculin. These cases show no manifest tuberculosis, but probably have some latent form. If tuberculin improves the condition, there must be some association between the nodular exudates and tuberculosis.

When the patient was under tuberculin treatment, relapses were very few; in fact, there was only one distinct case, and that was very slight. When other methods were employed, recurrent attacks were often seen.

Some of the patients returned for observation; the eyes appeared in good condition, there were no active inflammatory signs, and the general remark of the patients was that they were much improved.

It is necessary in some cases and at certain intervals to give another course of tuberculin injections. By this means we are more than able to hold the corneal ulceration in check and prevent opaque areas through the cornea. I feel confident that with the proper administration of tuberculin, accurate taking of pulse, temperature and respiration, and the general condition kept under surveillance, we can get good results from this way of handling the cases. It is far from perfect, but better than giving general tonics, with no special medicine given for a special ailment. The word "tonic" would not carry far if one were questioned why and for what reason the tonic was given.

Norman[1] says:

> Under tuberculin treatment the process of ulceration was arrested very much more quickly than by ordinary methods alone, and the resulting area of corneal opacity was correspondingly diminished. Another advantage is a remarkable freedom from relapse, but to ensure this we find it necessary to give the full course of fourteen injections in all cases.

The eyes were carefully observed and notes made after each injection, stating progress, or retrogression, or whether the eye was quiet.

The Department of Laryngology handled the cases of adenoids and tonsils. This removal was a great aid in the treatment. The examination of the adenoids and tonsils for microscopic diagnosis was thorough. Finding six cases with tubercle bacillus I think is

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1. Norman, A. C.: Tuberculin in Ophthalmic Practice, Hospital, London, 1915, **58**, 9.

exceptionally interesting. Their interest in the cases made the examination thorough and complete. Six cases were found positive for tubercle bacilli in the sections.

Miss Grace Pearson, our social service worker in the Department of Ophthalmology, did painstaking work in steering patients to the various departments for examinations and treatments. Had she not displayed so much interest in the work, our study would not have been complete. Her arguments with the patients about the importance of the treatment brought them back. Her observations and reports of housing conditions of the patients, and her instructions to the patients about the best way to live hygienically, the best way to get fresh air, the proper food and the like made her aid invaluable. I am indebted to her for her interest displayed in following these cases.

SUMMARY

I am not claiming this manifestation as a certainty of tuberculosis, but that in a majority of cases, if we use all methods of diagnosis we will find some evidence of symptoms that go with tuberculosis. In the seven cases showing active pulmonary signs (four of the patients having the tubercle bacillus in their sputum) it is satisfying to know that we aided the patients in getting the proper treatment.

The eye manifestation will at least make us think of a tuberculous involvement and will aid us in trying to check a tuberculous tendency. Tuberculin injections when properly and satisfactorily given are a great aid in our treatment. I have outlined eleven distinct points:

1. The nodular cellular lymphoid deposits, ulcerative and nonulcerative (phlyctenules) of the corneoscleral border are local eye manifestations of a constitutional dyscrasia, strongly suggestive of tuberculosis—if not tuberculosis, then something very closely associated, bearing a striking resemblance in its symptomatology to tuberculosis.

2. While the microscopic sections of these nodules show giant cells, it would not follow that the nodules are tuberculous, but rather indicate that the cellular infiltrate is a manifestation of the disease and not the cause.

3. The treatment has been hygienic and sanitary: sodium borate drops in nonulcerative case, and in corneal ulceration 1 per cent. atropin and protective glasses; tuberculin bouillon filtrate given in doses varying from 0.000001 gm. to 15 mg. At least thirty-five to forty treatments are demanded, and as high as fifty or more. Prolonged tuberculin treatment is important, and in doses averaging 0.0001 mg. I think at stated intervals it is advisable to renew tuberculin treatments. During tuberculin treatment eyes rapidly improve, and there were no recurrent attacks with the exception of one case, which was slight. Temperature, pulse and respiration were carefully watched. Any rise or tenderness and redness at the point of injection would indicate too strong a dose. The patient should *sustain toxins given* with *no reaction;* this is important.

4. Of the thirty-nine patients seven had pulmonary phthisis.

5. Sixteen had some form of tuberculosis as cervical adenitis or tuberculous bone.

6. Thirty-two had a positive von Pirquet reaction.

7. Eighteen had adenoids and diseased tonsils; the tubercle bacillus was found six times in microscopic sections.

8. Four showed tubercle bacilli in their sputum.

9. Eight physical examinations were suggestive of some form of lung involvement.

10. Thirteen had a Wassermann test with eleven negative.

11. Seven had a member of their family with tuberculosis.

Through the kindness of Dr. Robert L. Randolph, I was priviliged to use these cases in his clinic at the Johns Hopkins Hospital.

322 North Charles Street.

MEMORANDA

THE PATHOGENESIS OF OPHTHALMIA ECZEMATOSA

A PRELIMINARY REPORT *

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The acute interest of the profession in phlyctenular disease has been maintained for some time past, for two principal reasons: first, because the disease itself offers so much calculated to attract continued attention — its prevalence, complications, sequelae, and frequent recurrences — and second, because the problem of its pathogenesis is still *sub judice,* no one claim having succeeded in gaining a firm foothold in science.

As long as the etiology of ophthalmia eczematosa remains obscure, treatment will be empiric. Had we succeeded in accidentally finding a specific for the cure of phlyctenular disease such, for example, as we have in quinin for malaria and in mercury for syphilis, the fact that we have no absolute knowledge of the real causal factor would be only of academic interest; but, as will be seen, we have not been fortunate in discovering a specific as yet, and hence any investigation aimed at the finding of a cure of this troublesome malady must be in the form of a search for the causal factor of this form of ophthalmia.

Ophthalmologists throughout the world became much interested when a few years ago the teaching was promulgated that ophthalmia eczematosa, or phlyctenulosis, is due to either the tubercle bacillus or its toxins. Naturally the recognition of tuberculosis in some form as the cause of phlyctenular disease led to the application of a supposedly rational therapy. The entire antituberculous therapy, as tuberculin, ferruginous tonics, fresh air and overfeeding, was utilized against this disease, but unfortunately with no special result. The fact that the von Pirquet and other cutaneous tubercle tests yielded a surprisingly large number of positive reactions justified that therapy, but the comparatively insignificant clinical results certainly prove practically conclusively that the etiology of ophthalmia eczematosa is not tuberculosis.

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* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June, 1917. Publication rights reserved by the American Medical Association.

The only other important theory which has been advocated by competent observers is that the disease is due to intestinal fermentation. As will be seen later on, therapeutic experiments to confirm this hypothesis have proved negative.

It seemed to me that in this era of advanced pathology the inability to demonstrate the underlying cause of any form of ophthalmia must stand out as a reproach and that some light must be reached if a systematic search for it be made. That such a road is not devoid of difficulties is known to every one who has tried to secure diagnostic laboratory data of this disease. Might it not be that perhaps in this case the microscope and serologic tests are not the signs of the proper road? I did not answer that question when, a few years ago, utilizing a clinical material which exceeds 500 patients, I undertook to make an inquiry into the cause of ophthalmia eczematosa.

In presenting to the profession the results of this investigation no claim is made that this report is exhaustive, nor is it the intention to submit a detailed recapitulation of the scientific labors on this subject available in contemporaneous literature; but the mere narration, it is believed, is sufficiently convincing to show that the evidence, new though it be, is based on undisputable facts.

To begin with, the doubt of the tuberculous origin of the disease, justified by the repeated observation that patients treated for tuberculosis fared no better than those given other routine therapy, should cause the elimination of this theory from all calculations; but this, too, was included in the projected investigation.

Surgical therapy, and the use of vaccines and antitoxins have shown so conclusively negative results that these early were eliminated, not only as curative agents, but also as measures to indicate the causal factor or factors.

A plan was adopted to try with great care any drug at all likely to benefit the disease itself or at least its symptoms, on the presumption that if a really valuable agent be found an explanation of its rationale could possibly be arrived at and the desired goal reached. To prevent error, the routine practice of administering several drugs at one and the same time was abandoned, and each drug selected was studied singly. Boric acid, argyrol, protargol, silver nitrate, zinc sulphate, yellow mercuric oxid, mercuric chlorid, ethylmorphin hydrochlorid (dionin), atropin and similar drugs were subjected to thorough and prolonged therapeutic tests. It is evident that practically the entire ophthalmic, bactericidal and mydriatic armamentarium has been exhausted. The result of this inquiry can be given in one brief sentence: Not one of these drugs, with the single exception of atropin, had any real influence on the course of the disease. The findings are based on control observations, namely, that the drugs named, atropin excepted, had identically the same therapeutic results as those seen from the application of placebos. Atropin gave decided symptomatic relief, and in all probability was not without some curative influence.

It is interesting to note, however, that while the corneal phase of this disease does not respond to our classic bactericidal treatment, true corneal ulcer becomes clean and covered by epithelium; but this is as far as one can attain, for it continues to remain in a state of irritation, not unlike a nerve ending disturbance, similar to herpes zoster ophthalmicus, but milder than in this condition until the clinical entity has run its course.

In view of these results, all drugs were discarded and topical treatment restricted to the use of atropin irrespective of whether the cornea, conjunctiva or limbus was involved.

The evidence of the ineffectiveness of topical therapy clearly shows that the condition under consideration is not a localized disease, but a local manifestation of a systemic disturbance. The finding of the true underlying systemic cause, therefore, became the most important problem. The question which presented itself was by what method the desired result might be attained, since the aimless employment of the entire diagnostic armamentarium could have led only to confusion. Physical examination of the patients yielded the following data, which gave some index as to the best manner of search:

The greatest prevalence of the disease is between the second and twelfth years of life. Patients under

2 years of age are rarely seen. Seventy-five per cent. of the children were fairly well nourished. It is noteworthy that some of the most severe cases seen were in plump, ruddy children, to all appearances presenting an excellent degree of health.

This does not bear out the assertions of certain authors that phlyctenular disease is usually observed in anemic children with what is best described as a tuberculous habitus. The sexes were equally represented. The majority of the patients belonged to the poorer classes, in which the familes are large, and in which the environment from a hygienic standpoint is not wholly bad, except that individual parental control is exceedingly limited, the children being left almost entirely to their own resources. Adenopathy was manifest in the submaxillary, anterior and posterior cervical regions, the lymph glands being plainly discernible on palpation but rarely painful on pressure. The tonsils and adenoids were frequently enlarged and diseased. Skin and hair were characteristically dry. Erosions around the nostrils and behind the ears, especially where the two skin surfaces come in contact, were seen frequently. These erosions, which proved to be an intertriginous eczema, were often observed also in the inguinal folds, especially in very young children. Seborrhea of the scalp was not infrequent in the same class of children. A history of cough and loss of weight was seldom secured. Urinalysis, with special reference to the presence of albumin, sugar and indican, invariably gave negative results.

The routine eye examinations for this class of cases revealed nothing unusual as regards the clinical picture of the conjunctiva, limbus or cornea, and presented no statistical data of special significance. Could these manifestations be explained by tuberculosis? The most thorough search to sustain such a diagnosis by all available clinical agents proved futile. While there is no lack of ophthalmologists who still believe tuberculosis or tuberculous toxins to be the cause of phlyctenular disease, there are authorities who have emphatically rejected this theory.

Macnab,[1] quoting Axenfeld, says:

> Axenfeld has thoroughly disposed of the contention that phlyctenules are true tubercular lesions, and Mueller, in a

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[1] Macnab, Angus: Diseases of the Cornea, New York, William Wood & Co., 1907.

series of transplantation experiments in which fresh phlyctenules were introduced into the anterior chamber of rabbits, failed in every case to produce a typical tubercular lesion.

John W. H. Eyre,[2] hunterian professor and examiner in bacteriology of the Royal College of Surgeons, in his hunterian lecture on tuberculosis of the conjunctiva, says:

> That many of those subject to phlyctenules give evidence of the existence of tuberculous infection in some portion of their tissues is no evidence that the conjunctiva lesion is also tuberculous, and until some responsible observer has demonstrated the presence of the tubercle bacillus in an extended series of phlyctenules, I see no valid reason for regarding phlyctenulosis of the conjunctiva per se as a form of tuberculosis of the conjunctiva.

L. V. Hamman,[3] chief of the Phipps Tuberculosis Dispensary of Johns Hopkins Hospital, and co-author of Hamman and Wolman's work, "Tuberculin in Diagnosis and Treatment," says that if phlyctenulosis is a tuberculous manifestation it certainly some time should show the presence of the tubercle bacillus, and that the tuberculous toxin theory is fast losing ground.

George S. Derby[4] of Boston, who has treated a great many of these conditions with tuberculin, says:

> I have had considerable experience with tuberculin in the treatment of phlyctenulosis, and I feel doubtful whether any of these cases have been much benefited by it.

Brown and Irons[5] of Chicago recently reported on 100 cases of disease of the uvea, and in only two cases did they have a focal reaction with the subcutaneous test. This demonstrated the rarity of tuberculosis of the eye.

In common with the most universally accepted teachings, I have long abandoned the use of the skin test after the second year of life. In patients under that age only 35 per cent. gave a positive reaction, and that usually was a delayed local reaction, while the subcutaneous tests, which have been tried in a relatively small number of cases, rarely proved positive. Therapeutically the topical and subcutaneous use of tuberculin proved without effect. Tuberculosis as a factor in phlyctenular disease can therefore be absolutely set aside.

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[2] Eyre, J. W. H.: Lancet, London, 1912, **1**, 1319.

[3] Hamman and Wolman: Tuberculin in Diagnosis and Treatment, p. 209.

[4] Derby, G. S.: Disease of the Optic Nerve in Myxedema, The Journal A. M. A., Sept. 21, 1912, p. 1045.

[5] Brown and Irons: Paper read before the Chicago Ophthalmological Society, 1916.

Attempts to secure cultures from phlyctenules have not given satisfactory results, owing to the great difficulty in securing unmixed material from the papules even before they ruptured. As a rule the same flora was encountered which is commonly found in all conjunctival sacs, namely, staphylococcus, pneumococcus, diplococcus, *Micrococcus catarrhalis,* xerosis bacillus and others. Reliable workers have found the contents of unruptured phlycentules to be absolutely sterile.

While syphilis suggests itself as a possible factor, though no one has so far seriously considered it, this can be eliminated, since in the available material no data for such a diagnosis were even remotely present.

Finally, the removal of enlarged and diseased tonsils and adenoids for the purpose of influencing the ophthalmia, which had been strongly advocated some time ago, was subjected to a thorough test, but in spite of numerous radical enucleations no appreciable effect on the course of the disease could be demonstrated.

There remains the theory of intestinal putrefaction, which even at the present time has many advocates. The histories of all patients under observation show that their parents have seldom observed offensiveness of the stools. I made the Obermeyer test for indican in twenty-five cases, but no trace of this was discovered in the urine. This, however, need not be accepted as conclusive evidence for the absence of intestinal putrefaction. Though intestinal putrefaction could not be demonstrated through urinalysis, a number of patients were treated on the assumption that the intestinal disturbances actually existed. Suitable drugs, such as salol, calomel, acetylsalicylic acid, sodium salicylate, bismuth, sodium bicarbonate, liquid petrolatum and lactic acid bacillus either in pure bouillon culture, in tablet or in powder form, were administered, each single drug being subjected to a prolonged test.

It is interesting to note that, of all of the drugs used, calomel appeared to produce the most favorable results. This led to the adoption of an empiric routine, namely, atropin locally and calomel internally, as the most effective medicinal therapy.

It may be added that for some time the favorable results obtained from this combination encouraged the conviction that intestinal putrefaction was the solution of the problem, and the tentative acceptance pointed to the next step to carry the treatment to logical finality through the addition of the appropriate dietetic measures.

When the parents of the afflicted children were questioned, it was learned that fully 98 per cent. of the patients consumed an excessive amount of carbohydrates, especially in the form of sweets. At first I was inclined to pay scant attention to this feature. Further questioning, however, elicited the statement that these very children had little desire for plain, nutritious food. With a view of ascertaining whether or not this faulty diet had any decisive influence on phlyctenular disease, a practically carbohydrate-free diet was instituted in a series of cases as the single and sole method of treatment, excluding even the topical use of atropin, with the gratifying result that the children so treated did far better than with calomel and atropin alone. Later medication and diet were combined with exceedingly satisfactory results. The diet prescribed consisted of plain foods, as bread, butter, milk and eggs. This dietary cannot be regarded as ideal, but was the best available for external reasons.

These results were so striking that many interested colleagues who were familiar with this series of experiments admitted the striking improvements, but questioned the direct relation of the dietary to the favorable phenomena. As I was convinced that the dietetic regimen alone and unaided was the principal cause of the favorable course of this disease, another series of experiments was made which left no room for further doubt. A number of children whose affections had been under complete control were taken off the dietetic regimen, and given foods rich in carbohydrates. Almost at once this disease reappeared with the acuity of a pronounced relapse. These experiments were repeated at frequent intervals, and invariably yielded the same results.

The experience became so convincing that whenever patients presented themselves with a relapse, faulty diet was assumed and invariably admitted. Again and again the observation was made that relapses occurred when the parents ceased to exercise control over their children, enabling the latter to yield to the temptation to consume sweets. Naturally the question suggested itself whether the dietetic error, shown to exercise a decided influence on the course of the disease, was to be sought in the carbohydrates per se, or merely in the sweets. To answer this question, a control test was made in which ample doses of saccharin were administered as a substitute for the sweets. It was now uniformly observed that this coal tar product did not in the least show any unfavorable influence on the ocular manifestations, proving conclusively that the carbohydrates per se must be held responsible. Whether the unfavorable influence of carbohydrates is to be ascribed to faulty metabolism, or to a limited ability of assimilation of the carbohydrates, the excess probably undergoing chemical changes, which in turn yield toxic or irritating agents sufficiently effective to produce eczematous manifestations, must for the present remain an open question. As regards the modus operandi of whatever processes are responsible, we must look to physiology for an explanation.

It will be recalled that some time before the investigation was completed, the routine treatment of atropin topically, calomel internally and a carbohydrate-poor diet was found to yield the best results. The rationale of the administration of calomel needs no defense; but this drug has no bearing on the favorable influence of atropin, the latter having proved effective even without calomel. How can this be explained? Might it not be that in phylctenular disease we have actually to deal with a part of the picture of exudative diathesis as propounded by Czerny,[6] and that the external phenomena are the result of irritability or hypertonia of the vagus system?

If this is the case, atropin, and not calomel, is therapeutically the drug best suited. Accordingly, calomel was abandoned and atropin administered internally instead, in a series of cases, as suggested by the practice of Krasnogorski[7] and Leopold,[8] who prescribe a solution of atropin of 1 grain to the ounce of water in doses of 3 drops every three hours, and daily increase the dose by 1 drop until the physiologic effect is reached. A number of patients were treated by this method without stopping the topical applications of atropin and restriction of diet. The tolerance manifested by these children for this powerful drug is quite remarkable, some consuming as high as ⅓ grain daily.

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[6] Czerny: Exudativa Diathesa, Jahrb. f. Kinderh., 1905, p. 199; Scrofulosa and Tuberculosa, ibid., 1909, p. 529.

[7] Quoted by Leopold (Note 8).

[8] Leopold, J. S.: Atropine Treatment for Exudative Diathesis in Infancy, Am. Jour. Dis. Child, October, 1915, p. 288.

This form of treatment has now been extensively followed for the past eight months, and the results have been so greatly superior to any routine followed heretofore that, with the present experience as a basis, one cannot but say that absolute control of the symptoms of phlyctenular disease is assured by it. It must be emphasized, however, that while atropin best controls the symptoms, permanence of therapeutic results will depend on a strict adherence to a suitable diet even long after all the symptoms have disappeared.

It is realized that, in the presentation of the observations, workers accustomed to exact laboratory methods will find much that is not free from objections. It is conceded that in the further investigation of phlyctenular disease laboratory workers can find many unexplored avenues for scientific research. The investigation of the blood for the presence of acetone alone presents quite a problem. Chemical studies of carbohydrate metabolism and neurologic study of the vagus system are other fields of interesting activity. But the evidence so far submitted, clinical though it be, is too persistent and too extensive to be ignored.

I desire to express my sincere appreciation to the staff of the Illinois Charitable Eye and Ear Infirmary of Chicago for their courtesy in referring many patients to me for the purpose of furthering this investigation, and to Dr. A. Levinson, pediatrician to Michael Reese Hospital for Chicago, for many valued suggestions.

SUMMARY

1. Ophthalmia eczematosa or phlyctenular disease is not a true pathologic entity but symptomatic manifestation of a systemic disturbance.

2. Tuberculosis, syphilis and sepsis can be excluded with certainty as causal factors.

3. Phlyctenular disease is in all probability one of the expressions of vagus system irritability produced by some toxic agent, resulting from faulty carbohydrate chemism.

4. Correction of the chemism by carbohydrate-free diet and control of the vagus hypertonia through the topical and internal use of atropin yield the best and quickest possible therapeutic results.

MEMORANDA

INTRACAPSULAR EXTRACTION OF SENILE CATARACT

AN ANALYSIS OF ONE HUNDRED AND FORTY-SIX CONSECUTIVE CASES *

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AND

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In the accompanying tables are statistics of the cases of senile cataract in which we have operated by the intracapsular method in this country during the past two and a half years. Since as far as practicable we have had each patient report at frequent intervals for examination, we have had an excellent opportunity to study carefully 146 cases of senile cataract, the periods of observation ranging from one month to two and one-half years after operation.

In order to pass a judgment on the value of any operative procedure, it is self-evident that enough cases should be observed, and also that a sufficient length of time should elapse to note the remote as well as the immediate results of the operation.

The statistics on cataract operations generally available are often meager in details, the operator being satisfied to report only the visual results obtained at some unspecified time after his operation, and to incorporate in his tabulation of each case a few unessential points. The lack of important details in such statistics makes a comparison of results difficult if not impossible, for while vision may be high in from three to six months after operation, subsequent inflammation, glaucoma, epithelial downgrowth or the forma-

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* From the department of Ophthalmology, San Francisco Polyclinic.

tion of after-cataract or membrane, all frequently attributable to the operative procedure, may materially reduce the visual acuity first obtained. Therefore, in the report submitted herewith, along with other important data, the date of operation is followed by the date, vision, and correction at the first examination after operation, side by side with the same data for the last examination; thus the changes in vision and refraction, as well as the increase or decrease of vision at the final examination, are shown at a glance.

As a number of operations in this series were performed at state or government institutions outside the city, it was impracticable to make a complete examination before and after operation, so that in several instances the blood pressure and tonometric readings were unobtainable. Finger palpation was relied on when the tonometer was not used, and if the tension found was apparently normal, the operation was performed. Both systolic and diastolic blood pressure readings were taken, but in the tables it was considered sufficient to give only the systolic pressure. With institutional patients and in some private cases from outside the city, only one refraction subsequent to operation was obtainable, and in a few of the latter the refraction and visual result given are those reported by the home oculist.

We considered it advisable also to separate the complicated from the uncomplicated cases in order to appraise the operation at its true value. It is unnecessary to call attention to the fact that an operation may be a success from a surgical standpoint but a functional failure, and that this may be due to causes other than the operation and beyond the control of the operator, such as preexisting fundus lesions, corneal and vitreous opacities, general systemic affections, or conditions arising subsequent to the operation. In some of the cases in this series, the operation was undertaken with a full realization of the possible untoward results, for such cases were diagnosed as complicated before the operation; under this category come most of the cases with diabetes, chronic glaucoma and detachment of the retina. Fundus lesions, however, were frequently not diagnosed until later when the backgrounds could be seen after the removal of the cataract.

DATA

Method.—The method employed, except in twelve cases done by the Stanculeanu or the Knapp methods, has been in the main that known as the Smith Indian intracapsular cataract operation, the technic having been learned by us while in India under the personal instruction of Colonel Henry Smith.

Sex.—The sexes were divided about equally, there being no appreciable difference between them in tractability, convalescence or final results.

Age.—This varied from 35 to 95 years, and it seems to have had little or no bearing on healing or on recovery, but it did have a distinct influence on the delivery of the cataract. The older the patient, the weaker the suspensory ligament and the greater the ease of delivery. Again, age seems to have an influence on the maturation of the cataract; thus at 50 or under, only one was immature and bilateral, while six were mature and unilateral. The conclusion may be drawn, therefore, that the younger the patient the more likely it is for the cataract to be one-sided and mature when the patient comes under observation, while the older the patient, the greater the relative number of bilateral and immature cataracts presented. In patients under 50, and especially when only one eye was involved, the lens was harder to deliver within the capsule. These cataracts were probably secondary to some systemic affection or to a "quiet" form of uveitis. Vascular changes of the fundus were found more frequently in older patients.

Duration.—From the most reliable information we were able to obtain from the patient in cases in which the diagnosis of cataract had been made at an earlier period, some, we found, were ripe in six months or less, while others were still immature after thirty years; consequently it must frequently happen that a cataract does not become ripe within the lifetime of the patient.

Type.—For operative purposes we have classified cataracts into immature, mature and morgagnian or "tumblers." The immature includes cases of opacity from that degree at which the fundus is still to be seen to the stage at which no reflex can be obtained, but clear cortex remains; they constituted 63 per cent. of the entire series. The mature comprises cases in which no clear cortex remained; these constituted 29 per cent. Morgagnian or "tumblers" are the cases in which the lens substance has become partially or almost completely liquefied; these constituted 8 per cent. of our cases. This percentage of "tumblers" is higher than that usually reported, the difference, we believe, being due to the fact that in capsulotomy operation the diagnosis, from the very nature of the case, is difficult to make as the capsule is lacerated before the cataract is delivered, and it is likely to pass unnoticed unless the liquefaction is far advanced. In the intracapsular operation the diagnosis is readily made after the delivery of the liquefied lens in its intact capsule. In India the percentage of "tumblers" runs even higher, being from 25 to 30 per cent., owing to procrastination on the part of the native patient, which results in more advanced liquefaction of the lens.

Tension.—The intra-ocular tension ranged from 7 to 40, and was taken with the tonometer in all cases in which it was possible to do so. In the two hemorrhagic cases to be discussed later, Cases 2c and 17c, unfortunately, only finger palpation was possible, but the tension was apparently normal. Low tension seemed to have no bearing on operation or on results; high tension was not so innocuous apparently, for out of ten patients with a tension above 25, two had bad results, but in only one, Case 19, are we able to attribute this to the high tension. This patient had a chronic glaucoma with a tension of 32 and general arteriosclerosis. The other patient, Case 7c, had diabetes, arthritis deformans, and pus in the accessory nasal sinuses. In Case 32c, althought trephining and an iridectomy both failed to reduce the tension below 40, the tension was reduced to 16 after extraction of the cataract, and vision was raised from hand movements to $^{20}/_{150}$.

Blood Pressure.—The systolic pressure varied from 105 in Case 102 to 300 in Case 34c. As a prophylactic measure against intra-ocular hemorrhage, the high pressure was reduced by treatment before operation as far as possible in each case. In one, Case 2c, with intra-ocular hemorrhage, we have no record of the blood pressure; the other, Case 17c, had a systolic pressure of 156. Seven patients had a systolic pressure of 200 or over on the day of operation, so that it would seem that blood pressure has no very important bearing on the results.

Vision Before Operation—This ranged from $^{20}/_{40}$ to uncertain perception of light or faulty projection. Vision obtained before operation does not always give a positive indication of what it will be after operation. Thus Case 1c, with uncertain light preception before operation, ultimately had a vision of $^{20}/_{30}$, and Case 90, with a prior faulty projection, had ultimate vision of $^{20}/_{15}$; conversely, Case 25c had $^{20}/_{150}$ before operation and $^{10}/_{200}$ afterward, the reduced vision in this case being due to intercurrent retinal hemorrhages of diabetic origin.

Iridectomy.—Until January, 1916, we performed preliminary iridectomy in most cases, doing eight extractions, however, during the early part of that period without iridectomy; the latter procedure we found undesirable because in each instance the iris ultimately became adherent to the upper lip of the corneal wound, resulting in glaucoma and loss of useful vision in one instance, Case 6. Preliminary iridectomy was abandoned in January, 1916, in favor of the combined operation, as the former offered no advantages that were not more than offset by the added risk and inconvenience of a two-stage operation, and also because we have found that a limbal incision, with or without a conjunctival flap, such as we have been doing since that time, enables us to make a basal iridectomy. This we consider highly desirable and difficult to execute with the corneal section. A preliminary basal iridectomy interferes with the making of a good conjunctival flap subsequently.

The Van Lint flap was used twice, but was given up, as it required unnecessary manipulation, produced great trauma, and also subjected the eye to possible loss of vitreous while the sutures were being tied.

The Section.—In seventy-six of our cases a corneal section was used; in fifteen the section was limbal, while in fifty-five the usual conjunctival flap was made.

In studying the first half of the cases of this series, we found that a serious objection to the intracapsular operation as we then performed it was with the corneal incision; when the section must be so large as it is required to be for the intracapsular operation, it is certainly easier to make a corneal incision. This offers less impediment to the delivery of the lens, while at the same time it probably slightly reduces the danger from vitreous loss. But there are two serious objections to it: first, the greater frequency with which the iris adheres to the lips of the wound, and second, the liability of the downgrowth of epithelium from the wound into the anterior chamber. The latter factor, aside from other possible untoward results, usually materially reduces the vision, although a good reflex may be obtained with the ophthalmoscope. We believe that this downgrowth of epithelium is of more frequent occurrence in the capsulotomy operation than is realized, but is not so readily discernible here because the epithelium merges with the posterior capsule, or after-cataract.

This epithelial downgrowth occurred in five of our cases in which a corneal section was made, but in only one case in which the limbal section with conjunctival flap was employed. In the latter, Case 87, a large amount of vitreous was lost because of carelessness on the part of the assistant in handling the speculum; healing was delayed, a factor in itself conducive to epithelial downgrowth.

Complications During Operation.—In Case 31 the extreme tip of the knife was broken off while making the section, and was so small that it could not be found, nor would it respond to the Giant magnet. Vision was $^{20}/_{25}$ three weeks after the operation, but was reduced to $^{20}/_{120}$ seven months later by a "quiet" uveitis, which persisted for some time. We are unable to determine whether or not the accident was the cause of the uveitis. In the past few months the vision has gradually improved as the vitreous opacities have begun to clear up.

Iris Prolapse.—This occurred in ten cases, or 6.8 per cent.; of these, 4.1 per cent. occurred in those in which the corneal section was used, and 2.7 per cent. in the cases of limbal section with conjunctival flap. These results would also speak in favor of a limbal incision with conjunctival flap as opposed to the corneal incision.

Case 79 had iris prolapse with an attack of secondary glaucoma which was controlled by treatment, but nevertheless resulted in reduction of vision; no untoward results have occurred in the other nine cases.

In eight of these ten cases of prolapse, excision has been done.

Vitreous Loss.—Vitreous was lost in nineteen cases, or 13 per cent.

Seven had vision of 20/15.
One had vision of 20/20.
One had vision of 20/25.
Four had vision of 20/30.
One had vision of 20/40.
Three had vision of 20/60.
One had vision of 20/100.
One had vision of 20/200.

While vision was greatly reduced because of the loss of a large amount of vitreous in Cases 87 and 104, there was no complete failure on that account. In these two instances neither the operation nor the operator was to blame for the excessive vitreous loss. In the one case it was due to carelessness on the part of the assistant, and in the other to the extreme misbehavior of the patient. The loss of vitreous occurring through the operator's manipulation in an operation is much less to be feared than that resulting from the patient's squeezing, or to the assistant's carelessness, because in the first event a smaller quantity is usually lost.

Of the nineteen cases in which vitreous was lost, 63 per cent. were in patients 60 years of age or under, thus tending to show that the older the patient the more easily the lens is delivered, and bearing out the assertion already made that the suspensory ligament weakens progressively with age; in fact, our experience has taught us that patients may be too young for the intracapsular operation, but not too old.

Iritis.—Iritis occurred in five cases, or about 3.5 per cent. In Case 31, as already mentioned, the point of the knife was broken off and never found; Case 51 was a morgagnian cataract with a ruptured capsule; Case 7c was in a diabetic and there was an accessory sinusitis; and in Case 12c there was a sympathetic ophthalmia from a previous cataract operation on the other side. This leaves only Case 44 with an unexplained primary iritis following operation.

Iridocyclitis.—This occurred once in the series, in Case 26. This patient was one among several exhibited during the American Medical Association session in

San Francisco. She was handled carelessly while being moved by mistake from one ward to another, during which time she had also a severe coughing spell. The wound was opened and vitreous extruded; the result was a soft eye with vision reduced to light perception.

Suppuration.—Despite the prevalent belief that loss of vitreous is conducive to infection, suppuration did not occur in any of our cases, with or without the loss of vitreous.

Intra-Ocular Hemorrhage.—This occurred in two cases. In Case 2c, the tension by finger palpation was apparently normal, but there was glaucoma simplex of the other eye. In Case 17c, the patient was a diabetic, and had had a cerebral hemorrhage one year prior to this with partial recovery. In both of these cases light perception was lost.

Glaucoma.—Glaucoma occurred twice. Case 6 was a simple extraction with a round central pupil two weeks after operation. This patient repeatedly showed the wound to friends by drawing up the upper lid and forcibly looking downward; this caused a stretching of the wound and the development of an astigmatism of 8 D.; two months after operation the vision was $^{20}/_{15}$. In time the upper part of the iris became adherent to the wound, and when the patient returned after an absence of six months the tension in that eye was 52 with vision reduced to perception of light; the disk was deeply cupped. Under treatment, vision was improved to $^{1}/_{200}$, March 1, 1917.

In Case 79, there was a prolapse of the iris and a lens that was hard to dislocate; three weeks after the operation, vision was $^{20}/_{30}$. Three months later an attack of acute glaucoma developed; the iris was released from the angle of the wound, but vision had deteriorated to $^{20}/_{100}$. Tension is gradually going down and vision improving.

Retinal Detachment.—This occurred in two cases. In Case 3c, after an uneventful operation and convalescence, the patient was accidentally struck in the eye with a chair; the wound was opened, vitreous was lost, and the pupil distorted. After a delayed recovery, the patient's vision was $^{20}/_{15}$ for four months; then suddenly the retina became detached. The retinal tear could be seen on the lower nasal side; vision now amounts to light perception.

In Case 10c, the patient was struck in the eye with the hard brim of a visitor's hat; the wound was opened, vitreous was lost, and the pupil distorted. Healing was delayed, but the patient's vision fifteen months after the operation was $^{20}/_{25}$. The retina became detached, Jan. 26, 1917, vision now being limited to light perception.

We believe that the results in these two cases are to be attributed directly to the accidents which the patients sustained.

Ruptured Capsules.—The capsules were ruptured in ten cases, or 6.8 per cent., which included several in which the Kalt or the Stanculeanu forceps had been used to dislocate the lens; the capsules were subsequently removed in three of these cases.

Secondary Operations.—In seven cases, secondary operations were necessary to improve vision, being less than 5 per cent. Three of these were for the extraction of retained capsules, and four were cases in which an iridectomy was done to lower a drawn-up pupil.

Previous Operations.—Fourteen patients of this series had been previously operated on by other operators for cataract of the opposite eye, the results varying from mere light perception to total failure; the eyeball was usually shrunken and soft, and beyond all hope of redemption. The vision of the eye on which we operated is given in Table 3. The low vision in some of these cases was due either to the results of sympathetic ophthalmia from the opposite side, or to extensive fundus lesions.

TABLE 3.—VISION OF EYE ON WHICH OPERATION WAS PERFORMED BY US

Case 16	20/15.
Case 27	20/15.
Case 41	20/15.
Case 76	20/15.
Case 100	20/20.
Case 27c	20/20.
Case 22	20/25.
Case 88	20/25.
Case 31c	20/60.
Case 22c	20/60.
Case 12c	20/80.
Case 104	20/200.
Case 7c	10/200.
Case 6c	1/200.

Diabetes.—This was a complication in eight cases. In all an attempt was made to put the patient in the best possible condition before operation, and the sugar reduced to the limits of safety. Patient 17c had an intra-ocular hemorrhage on the table a few moments after the delivery of the cataract, causing a complete failure. A year prior to the operation she had had a cerebral hemorrhage with partial recovery.

TABLE 4.—RESULTS IN DIABETICS *

Case 75, ultimate vision	20/20.
Case 23c, ultimate vision	20/20.
Case 29c, ultimate vision	20/100.
Case 8c, ultimate vision	20/100.
Case 7c, ultimate vision	10/200.
Case 25c, ultimate vision	10/200.
Case 17c, total failure from hemorrhage.	
Case 28c, death five days after operation from diabetic coma; eye in good condition.	

* Reference to Tables 1 and 2 will show additional complications.

The prognosis in the case of diabetic patients is poor, as a rule, for the visual results are often disappointing. In all but Case 17c, healing was uneventful; in four others, visual results were poor, owing to diabetic changes in the fundus or to uveitis. Two patients, however, had vision of $^{20}/_{20}$. These results would cause one to consider carefully the advisability of operating on a patient with diabetes, and the general condition, the degree of visual disability, and the functional condition of the retina should be given careful consideration.

Refraction After Operation.—In studying the tables, one is struck by the change in refraction and the improvement in vision between the first and the last examinations recorded.

At the first examination, usually occurring within four weeks after the operation, astigmatism as high as 10 D. was found, the average being 4½ D.; after two years the highest astigmatism was 8 D., in Case 6, while many cases lost the astigmatic element entirely, the average being 2 D. The reason for the 8 D. persisting in Case 6 has already been explained; this is the only case in our series in which such a high degree of astigmatism persisted for an extended period.

With the decrease in the astigmatism, the hypermetropia usually increased. Contrary to the common conception, there was no appreciable difference in the amount of astigmatism that developed in the corneal incisions as compared with the limbal sections, or those with a conjunctival flap. In the majority of cases, astigmatism was against the rule, approximately at axis 165 for the right eye, and axis 15 for the left. The spherical error averaged 10 D.

A condition not shown by the tables was that the astigmatism markedly increased during the first week the patient used his eyes. On examination immediately after the removal of the dressings, which had been left on for ten days after operation, usually no astigmatism, or less than 2 D. was found, but it developed or increased during the first week, for we found that after the patient had used his eyes for a few days, astigmatism as high as from 8 to 10 D. was sometimes present; this we attribute mainly to the stretching of the wound by the downward pull of the depressor muscles. But the astigmatism decreased after the first few weeks as the wound grew stronger, until at the end of a year frequently no astigmatism remained. In Cases 6 and 10, the right and left eyes of the same patient, 5 D. of astigmatism in one eye and 8 D. in the other were developed by the patients looking downward to show the operative scar to her friends; this astigmatism remained permanently. Since that experience we have cautioned our patients to refrain from looking downward, and enforce it by having them wear spectacles, the lower halves of which are covered with adhesive plaster, so that the tendency to look downward is reduced to a minimum. These are worn for about two weeks after the removal of the dressings.

Visual Results.—Only the visual results of the uncomplicated cases are summarized, in order to form a proper basis for a fair judgment as to the results obtained, the final vision in the complicated cases, as previously stated, being dependent on factors other than operative. The visual results of these complicated cases may be studied by referring to Table 2.

It is worthy of special note that sixty-nine, or 63 per cent. of the series, were cases of immature cataracts. These patients would have been condemned to partial blindness if they had had to wait for their cataracts to become mature before operation. Another point of special interest is the fact that despite the greater frequency with which vitreous was lost in the immature cases, the visual results are higher than in the mature and morgagnian cases. Thus of the 69 cases of the immature, 68 patients, or 98.55 per cent., had vision of from $^{20}/_{120}$ to $^{20}/_{15}$, and 66 patients, or 95.65 per cent., had vision of from $^{20}/_{40}$ to $^{20}/_{15}$; of the 40 mature, including morgagnian, 38 patients, or 95 per cent., had vision of from $^{20}/_{200}$ to $^{20}/_{15}$, and 33 patients, or 82.5 per cent., had vision of from $^{20}/_{40}$ to $^{20}/_{15}$. Placed side by side for comparison these results are given in Table 6.

TABLE 5.—SUMMARY OF VISUAL RESULTS OF ONE HUNDRED AND NINE UNCOMPLICATED CASES

20/15	40 cases
20/20	24 cases
20/25	9 cases
20/30	15 cases
20/40	6 cases

A total of 94 cases, with vision from 20/40 to 20/15, equivalent to 86.2 per cent.

20/60	4 cases
20/80	1 case
20/100	3 cases
20/200	1 case
10/200	1 case
1/200	1 case
L. P.	1 case

Not included in the foregoing are three patients who left the county hospital without reporting for refraction, but whose vision on cursory examination was good.

Taking as our basis of comparison Herman Knapp's visual standard of

20/20 to 20/200	first class,
18/200 to 1/200	moderate results,
L. P. to loss of L. P.	failure;

we have obtained the following results:

First class	97.25 per cent.
Moderate	1.83 per cent.
Failure	.92 per cent.

TABLE 6.—COMPARISON OF USUAL RESULTS

	Immature		Mature	
Vision	No. of Cases	Per Cent.	No. of Cases	Per Cent.
from 20/120 to 20/15	68	98.55	38	95
From 20/40 to 20/15	66	95.65	33	82.5

CONCLUSIONS

1. A limbal section, preferably with a conjunctival flap, is more desirable than a corneal incision.

2. There is no appreciable difference in the amount of astigmatism resulting after a corneal section as compared with a limbal, with or without a conjunctival flap.

3. The simple extraction is not well adapted to the intracapsular operation.

4. The combined extraction has several advantages over a two-stage operation with a preliminary iridectomy.

5. While all forms of senile cataract can be successfully removed by the Smith Indian intracapsular cataract operation, the immature cataract is the type that lends itself best to this procedure, especially in patients past the age of 60.

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MEMORANDA

REPORT OF THE COMMITTEE ON COLLECTIVE INVESTIGATION CONCERNING THE OCULAR MUSCLES *

In the last report made by this committee,' a brief review was given of what had been accomplished, and the plan of further study proposed. It was pointed out that, as convergence and all questions concerning the action of the extra-ocular muscles are more or less related to accommodation, it therefore seemed desirable, first of all, to separate as clearly as possible what we do know from what we do not know concerning the latter important function. We found we could all agree that accommodation was essentially the result of an effort made by the ciliary muscle. We recognized the changes which normal accommodation undergoes with advancing years, and saw how it was influenced by the "minimum doses" of certain miotics, and cycloplegics, the term "minimum dose" indicating the smallest amount which has been found sufficient, by repeated experiment, to produce the characteristic effect on a normal eye of a given amount of a given drug in a given number of minutes.

Having thus cleared up the ground, in part at least, by deciding as best we could certain mooted points, our committee recommended that the attention of the section be directed next to anomalies of accommodation.

The importance of this aspect of ophthalmology is well stated by Duane when he says:

> Considering the amount of attention devoted to refractive errors and their correction, the study of accommodative anomalies has received comparatively little attention from ophthalmologists. Yet those who deal day after day in their consulting-rooms with the problems of refraction work recognize, I am sure, that these anomalies often occasion considerable trouble, so that if we fail to diagnosticate and treat them, we are not doing our whole duty to our patients.

In spite of this we do not yet have any standard method by which to determine when excessive or insufficient accommodation does exist or for expressing the degree which is present. The result is that widely different views are held as to the frequency of anomalies of accommodation. Some writers, for example, consider that spasm of accommodation is comparatively rare, while Schmidt-Rimpler and others would have us believe that this spasm can be found in a quarter or, with certain groups of ametropia, in more than half our cases.

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* This paper has been accepted by the Executive Committee of the Section on Ophthalmology of the American Medical Association, to be presented before the section at the New York session, June, 1917. Publication rights reserved by the American Medical Association.

Evidently the reason for this difference is in our methods of examination and in the definitions of what we find.

Let us therefore consider, first, excessive accommodation, in order to agree, if possible, on the method to be followed, in principle at least, in making the successive tests, and also on the symptoms which we are to consider sufficiently characteristic to warrant that diagnosis.

A categorical statement of these points gives no opportunity for explanations, but it has the merit of brevity.

For the diagnosis of any anomaly of accommodation we probably agree that we should know: (*a*) The age of the individual; (*b*) the refraction of the eye as determined by placing at least 0.00025 gm. (1/250 grain) of atropin on the conjunctiva and making careful tests of the refraction not less than forty minutes nor more than two hours thereafter, and (*c*) any cause which materially affects the general nervous system of the patient.

For the diagnosis of excessive accommodation or spasm we shall probably also agree that:

1. The range of accommodation is restricted as compared with that of the otherwise normal eye. The near point is too near and the far point also may be approached—that is to say, an emmetropic eye may appear to be myopic. Under such circumstances if we apply a sufficient quantity of atropin to relax any existing excess of accommodation, the amount of this apparent myopia, which has disappeared under the influence of the cyclopegic, measures, of course, the degree of excessive accommodation which was present. This is a diagnostic symptom.

2. Measurement of the relative accommodation shows that the positive part is greater and the negative part less than normal. This symptom is also diagnostic, especially as concerns the relaxation of the accommodation to the convergence.

3. A minimum dose of certain cycloplegics usually causes the ciliary muscle to relax less rapidly than normally.

4. A minimum dose of certain miotics usually causes the ciliary muscle to contract more rapidly than normal. The curves for these minimum doses of certain cycloplegics and miotics have been published in previous reports of this committee and elsewhere.

The evidence furnished by the third and fourth tests is only corroborative, not diagnostic.

What has been said in regard to the diagnosis of excessive accommodation applies also to insufficient accommodation, if we understand that, *mutatis mutandis,* the conditions are the same.

One practical point may be mentioned, however. Since the normal eye in early life has the power of accommodation of about 3 diopters when the visual axes are in the primary position, that is, when they are parallel perpendicularly to the base line and in the horizontal plane, then a patient should be able to see a given test type in the distance as well with a minus 3 spherical before the eye as without that glass—any ametropia of course which exists having been corrected. This has been already stated. In view of the simplicity of this test, our results could be more uniform if this use of a minus 3 diopter glass formed a part of routine examinations.

As the terms "excessive" or "supernormal" accommodation and "spasm" of accommodation are used interchangeably, and as the terms "insufficient," "subnormal," "paresis" and "paralysis" of accommodation are also used interchangeably, and as it is desirable for us to ascertain and also to express in our records, and in any published statement, not only the kind but also the degree of the anomaly of accommodation, therefore our committee recommends that we should use the terms describing these anomalies as follows:

1. *Excessive Accommodation.*—A generic term to describe any degree of accommodation greater than normal in a person of a given age.

2. *Supernormal Accommodation.*—An excessive accommodation of less than 1 diopter.

3. *Spasm of Accommodation.*—Excessive accommodation greater than 1 diopter.

4. *Insufficient Accommodation.*—A generic term to describe any degree of accommodation less than normal in a person of a given age.

5. *Subnormal Accommodation* or *Paresis of Accommodation.*—An insufficient accommodation of less than 1 diopter.

6. *Paralysis of Accommodation.*—Insufficient accommodation greater than 1 diopter.

It is too much to expect that every member of the section will take the trouble to make all or even a part of these tests in the routine of office work. Certainly not every one would care to indicate in his records the special variety of an anomaly of accommodation which might be found. But the approval by the section of the few recommendations here made would be at least a convenience to American ophthalmologists who are inclined to do exact work, and it would also be an expression of the desire of the section for even a little more scientific accuracy.

Several other points might be brought forward in this connection. But the principal object of such a committee as this is to act as a clearing house to bring into accord and unify terms and methods which we employ. It is desirable, therefore, to make these reports always conservative and submit for approval only a little at a time.

In concluding this report, acknowledgments should be made to members of the section and to others who are cooperating in this collective investigation. As they have not been studying excessive accommodation, however, due notice of their work must be deferred until later.

It is hoped that the present suggestion to establish a standard for the diagnosis of excessive action of the ciliary muscle may at least tend to lessen some of the confusion which exists in our discussions and in our literature. We appreciate that the recommendations are few and simple, and relate only to one small phase of a large subject. But with patience in clearing up thus one point after another, we hope that some substantial progress can ultimately be made in our knowledge of the ocular muscles.

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